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VOLUME VI

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DOCUMENT NUMBER

QTR-2191-001

REV. N/C

TITLE

QUALIFICATION TEST REPORT FOR 450 GALLON CRASHWORTHY FUEL TANK FOR U.S. AIR FORCE H-53 HELICOPTER

TEST PERFORMED BY

FIBER SCIENCE DIVISION

CONTRACT NUMBER

F09603-79-C-1642-P20002

PREPARED BY

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APRIL 2, 1982

FIBER SCIENCE DIVISION

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PREPARED FOR

WARNER ROBINS ALC/MMSRCB

ROBINS AIR FORCE BASE, GEORGIA 31098

APPENDIX B

QUALIFICATION TEST REPORTS

QTR-2191

SECTION S.

CRASH IMPACT TEST

Universal Report No. QTR-2191 Section "S"

Dynamic Science Report No. 4111-81-054/1878
Revision

REPORT OF: Crash Impact Qualification Tests of Fiber Science 450 Gallon Filament Wound, Lightweight, Explosion Proof, External Fuel Tank for H-53 Helicopter.

TESTS PERFORMED BY:

Dynamic Science, Inc.
1850 W. Pinnacle Peak Rd.
Phoenix, AZ 85027

TESTS AUTHORIZED BY:

Fiber Science, Inc.
Salt Lake International Center
506 Billy Mitchell Rd.
Salt Lake City, UT 84116

Contract No. F09603-79-C-1642

	Date	Signature
Test Initiated	3/26/81	(contract award)
Test Completed		
Report Written By	6/9/81	
Supervisor	6/9/81	
FSI Test Engineer		
Supervisor		
Government Repr.		
Final Release		

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LIST OF ILLUSTRATIONS (CONTD)

LIST OF ILLUSTRATIONS (CONTD)

1.0 INTRODUCTION

1.1 PURPOSE AND BACKGROUND

The tests described in this report are Crash Impact Qualification Tests of the 450 Gallon Filament Wound, Lightweight, Explosion Proof, External Fuel Tank for the H-53 series helicopter.

The Crash Impact Test is described in Paragraph 3.4.1.7.5 of Technical Exhibit ASD/ENFEA-78, October 1978:

> "The tank design shall be capable of withstanding without rupture, when full, ground impact loads induced by a combined vertical velocity component of 40 fps and a longitudinal velocity component of 45 fps. Total allowable leakage is 1000 cc per minute maximum. Tank impact attitude shall be between 0° and 15° nose-up."
>
> NOTE: The velocity components in the above paragraph are for fuel tanks filled with fuel. For the test described in this report, water was used instead of fuel. The velocity components were adjusted downward to compensate for the greater density of water.

The crash-proof external tank was originally suggested in Mishap Control No. WR76-022A.

These tests were performed for Fiber Science, Inc., by Dynamic Science, Inc. at its test facility in Phoenix, Arizona.

This report was prepared by Dynamic Science, Inc. excluding Section 1.4, "Conclusions and Recommendations." Those portions of Data Sheet 2 requiring cross-sectioning of the tank, and those sections of Data Sheet 2 pertaining to Evaluation of Data, all of which were prepared by Fiber Science, Inc.

1.2 DESCRIPTION OF TEST SAMPLES

The samples used in this test series were prototypes of the 450 Gallon, Filament Wound, Lightweight, Explosion Proof, External Fuel Tank for the H-53 series helicopter. These tanks were developed and fabricated by:

FIBER SCIENCE, INC.
Salt Lake International Center
506 Billy Mitchell Road
Salt Lake City, UT 84116

under Contract No. F09603-79-C-1642 from USAF Logistics Command, Warner Robins Air Logistics Center. The tanks were designated by Fiber Science, Inc. as Part Number 2191-001A, and were all manufactured in April 1981.

1.3 DISPOSITION OF TEST SPECIMENS

Following post-test examination by Dynamic Science, Inc. for the purpose of recording the data contained in this report, the test specimens were returned to Fiber Science, Inc. for further analysis.

1.4 CONCLUSIONS AND RECOMMENDATIONS

1.4.1 Crash Impact

Crash impact testing was performed on three tanks, serial numbers 0002, 0003, and 0004 with only partial success. Although the tank did not break up completely, the rupture cracks were large enough to allow leakage well in excess of the specification requirements. Two tanks were dropped full of water from the specified height. The remaining tank was dropped full of water from a height of 16 feet.

1.4.2 Crash Impact Analysis

From subsequent structural analysis and testing done by Fiber Science on scale models, it was determined that the frames of the tank were too flexible in the lower portion, causing the overall tank structure to be too flexible and break up under high bending loads.

1.4.3 Crash Impact Recommendations

It is Fiber Science's recommendation that this test be rerun after a redesign of the frames and other aspects of the tank to increase its stiffness. Fiber Science would also recommend that the tank be dropped only 16 feet instead of the specified 25 feet. The 25 foot height seems excessive since it is greater than the helicopter personnel can withstand and it is also higher than the drop test required for the United States Navy CH-53E 650 Gallon Tank. The CH-53E tank is drop tested at 16 feet.

1.5 REFERENCES

1. Technical Exhibit ASD/ENFEA-78, October 1978.
2. Mishap Control No. WR76-022A.
3. "Qualification Test Procedure, H-53 Tank, Requirements for Crash Impact Test," Fiber Science, Inc., Document Number QTP-2191 Section "S," December 1980.

2.0 FACTUAL DATA

2.1 DESCRIPTION OF TEST APPARATUS

Table 2-1 presents a summary of all instruments and equipment used for the collection of electronic data, the manufacturer's names, instrument serial numbers, ranges, accuracy, and dates of latest calibration. All non-electronic data (i.e., static measurements) were obtained through the use of standard measurement techniques.

TABLE 2-1. CRASH IMPACT INSTRUMENTATION AND TEST EQUIPMENT SUMMARY

Item	Model	Manufacturer	Serial No.	Range	Accuracy	Date of Last Calibration
Strain Gages	CEA-06-2500T-350	Micro Measurements	Lot #R-A40AD00	5%	±5%	None
Pressure Transducers	PA220TC-1.25M-350	Statham	1229 1239	0-1250 PSIA	±0.79% ±0.19%	5-11-81 5-11-81
Pressure Transducer	PA226TC-1M-350	Statham	933M	0-1000 PSIA	±0.142%	5-11-81
Pressure Transducer	4-326-0008	CEC	13916	0-1500 PSIA	±0.22%	5-11-81
Accelerometers	2264-2000	Endevco	AJ16 AN61 AN81	±2000g	±0.29% ±0.10% ±0.11%	4-22-81 3-04-81 3-04-81
Fifth Wheel Velocity Meter	Tracktest DD1.1	Labeco Labeco	1555 7250	0-100 mph	±1.0%	Cal Before Use Cal Before Use
Fifth Wheel Calibrator	VC 1002	Dynamic Science	1002	52,95 mph	±0.05%	3-09-81
1000 PPS Camera	Hycam 41-004	Red Lake Laboratories	1228/2486 H1	20-11,000 PPS	Determined from timing marks	None
1000 PPS Cameras	16-1B	Photosonics	1185-P6 1291-P8	500 & 1000 PPS	Determined from timing marks	None
400 PPS Cameras	DBM-5A	Millikens	6549-M8 6548-M7	64-400 PPS	Determined from timing marks	None

TABLE 2-1. CRASH IMPACT INSTRUMENTATION AND TEST EQUIPMENT SUMMARY (CONTD)

Item	Model	Manufacturer	Serial No.	Range	Accuracy	Date of Last Calibration
100 Hz Camera Timing Generators	None	Dynamic Science	M8 M7 P6 P8 H1	100 Hz 100 Hz 100 Hz 100 Hz 100 Hz	Checked and recorded before use	1-14-81 1-20-81 1-14-81 4-01-81 1-12-81
Camera Timing Frequency Counter	MAX 100	Continental Specialties Corporation	17692	100 Hz-100 MHz	1 Hz (1% at 100 Hz)	3-16-81
Remote Signal Conditioning Module	M140	Ectron	3081 3082	*	*	Cal Before Use
Telemetry Transmitter	CTP-501-05 5 watt	Conic	5010001 5010004	*	*	None None
Telemetry Reciever	CRS-501	Conic	101	*	*	None
Instrumentation Tape Recorder	Sabre III	Sangamo	7153	*	*	1-28-81
Playback Tape Recorder	Sabre III	Sangamo	7628	*	*	1-28-81
FM Demodulators	GFD-15/TU01	Data Control Systems	1073501 thru 1073523	*	*	Cal Before Use
Butterworth Analog Filters	4122	Ithaco	25745 thru 25751	*	*	3-06-81
A/D Converter	DAS-6000	Phoenix Data, Inc.	B5978	8 KHz sample rate	±0.03%	None
Computer	Eclipse S130	Data General	15903-1 359	-	≤2.72%**	None

*The Dynamic Science data acquisition system provides a flat, linear response up to 1 KHz with ±5% error.

**Error due to propagation of truncation error through the FFT digital filter.

2.2 TEST PROCEDURE

The requirements of the Crash Impact Test are as stated in Section 1.1. The pass/fail criteria for the test is the amount of leakage. All other data presented in this report are for information purposes only. Section 2.2.1 describes the Crash Impact procedure. Section 2.2.2 describes the electronic data acquisition process. Section 2.2.3 describes photography.

2.2.1 Crash Impact Test Procedure

The test procedure generally followed the outlines given in Fiber Science, Inc. Document No. QTP-2191 Section "S", "Qualification Test Procedure, H-53 Tank, Requirements for Crash Impact Test."

In order to drop the fuel tanks from a height at a specified forward velocity, a mounting fixture was devised to hang the tank under the boom of a crane, as shown in Figures 2-1 and 2-2. The tanks were equipped with the Sargent-Fletcher Company P/N 27-450-4400 Center Section Pylon Assembly. The Pylon Assembly was attached to a Qualification Test Fixture built by Fiber Science, Inc., designed to simulate the actual aircraft attachment. The Qualification Test Fixture was attached to the crane boom by means of the steel framework evident in Figure 2-3. Figure 2-4 shows the pylon/test fixture/framework interface.

After mating the pylon to the Qualification Test Fixture, the crane boom was raised until the tank was in the proper attitude, and colored water was introduced at the aft filler opening. The crane boom was then lowered to the proper test attitude.

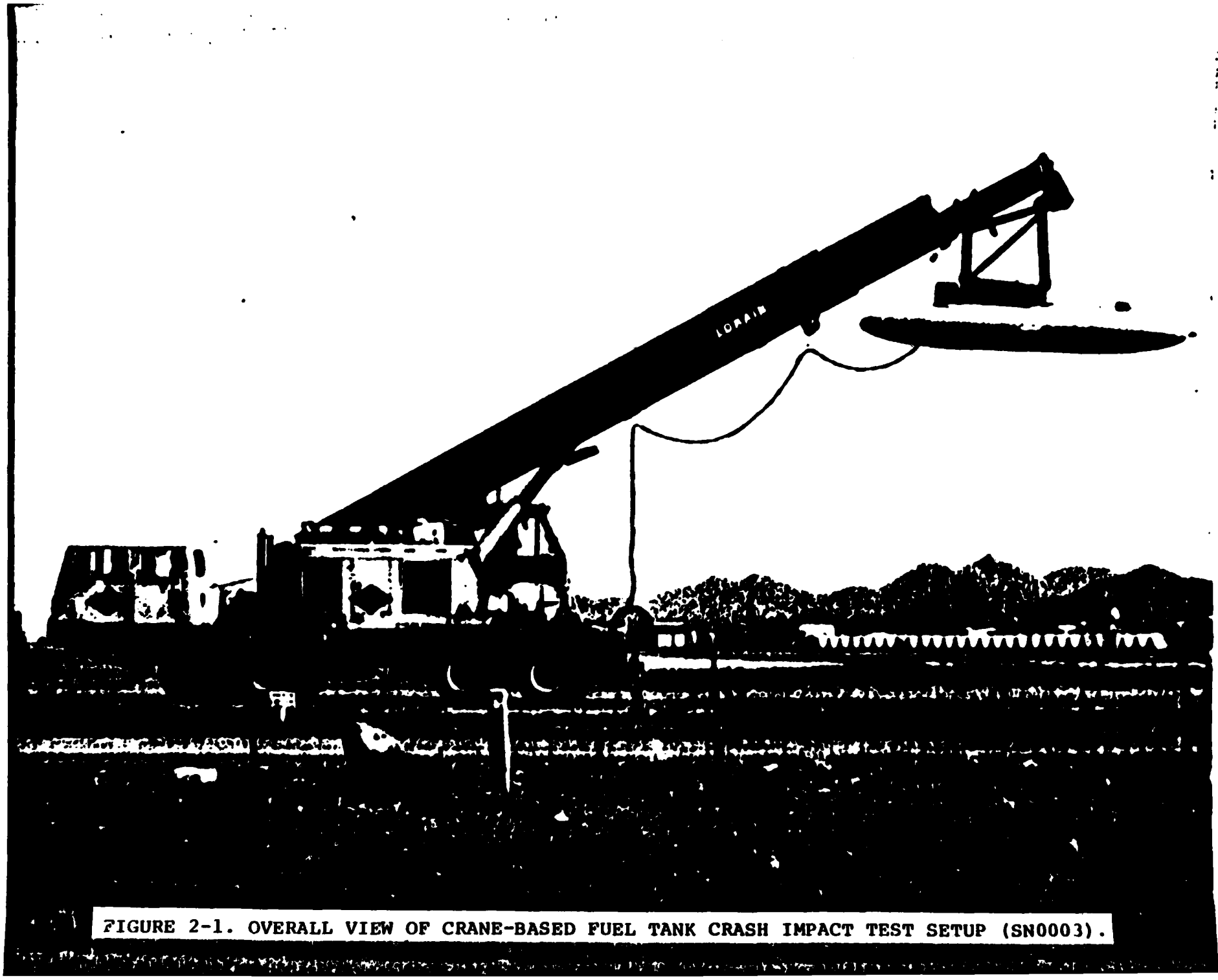


FIGURE 2-1. OVERALL VIEW OF CRANE-BASED FUEL TANK CRASH IMPACT TEST SETUP (SN0003).

FIGURE 2-2. LEFT FRONT THREE-QUARTER VIEW OF CRANE-BASED FUEL TANK CRASH IMPACT TEST SETUP (SN0003).

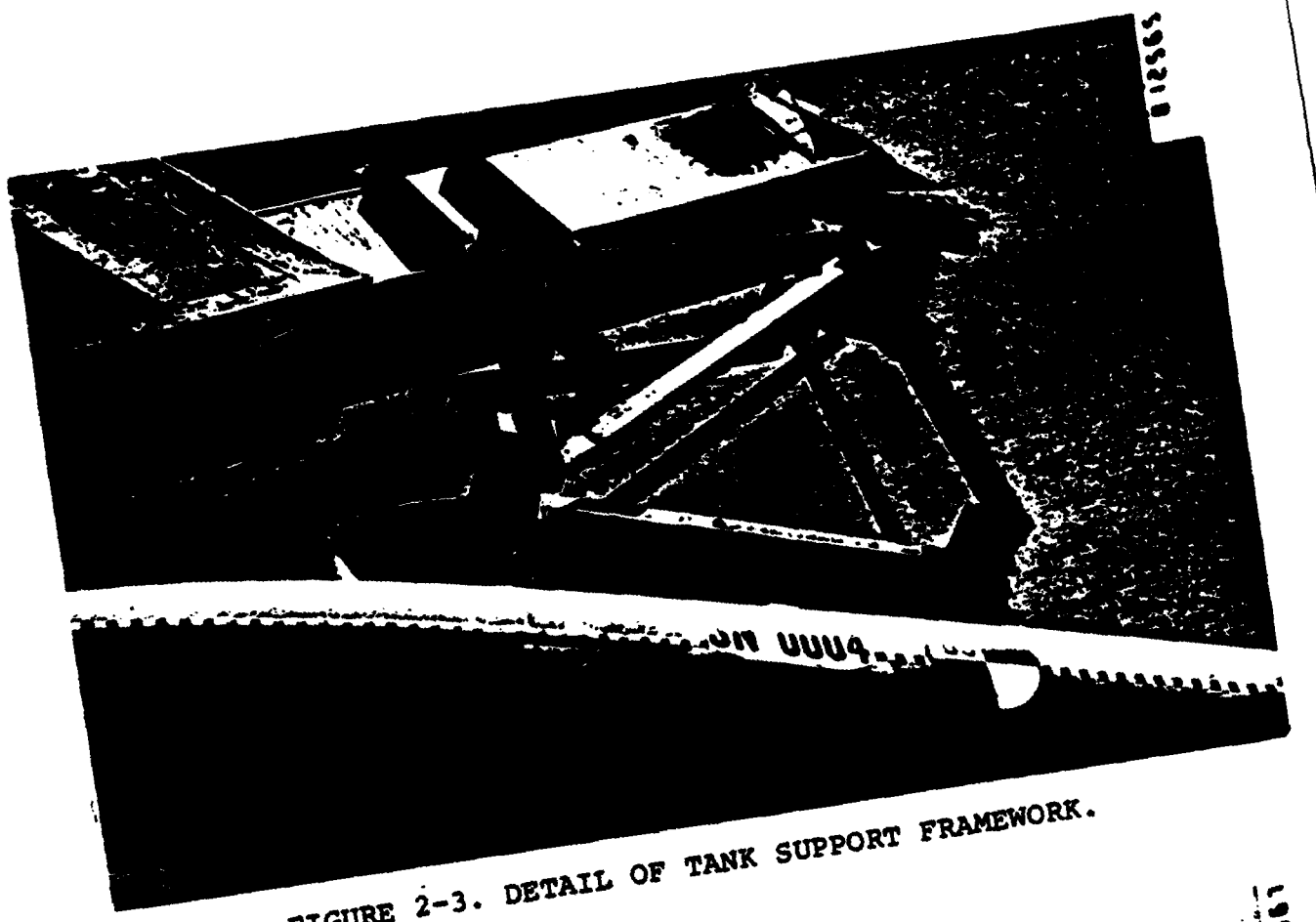


FIGURE 2-3. DETAIL OF TANK SUPPORT FRAMEWORK.

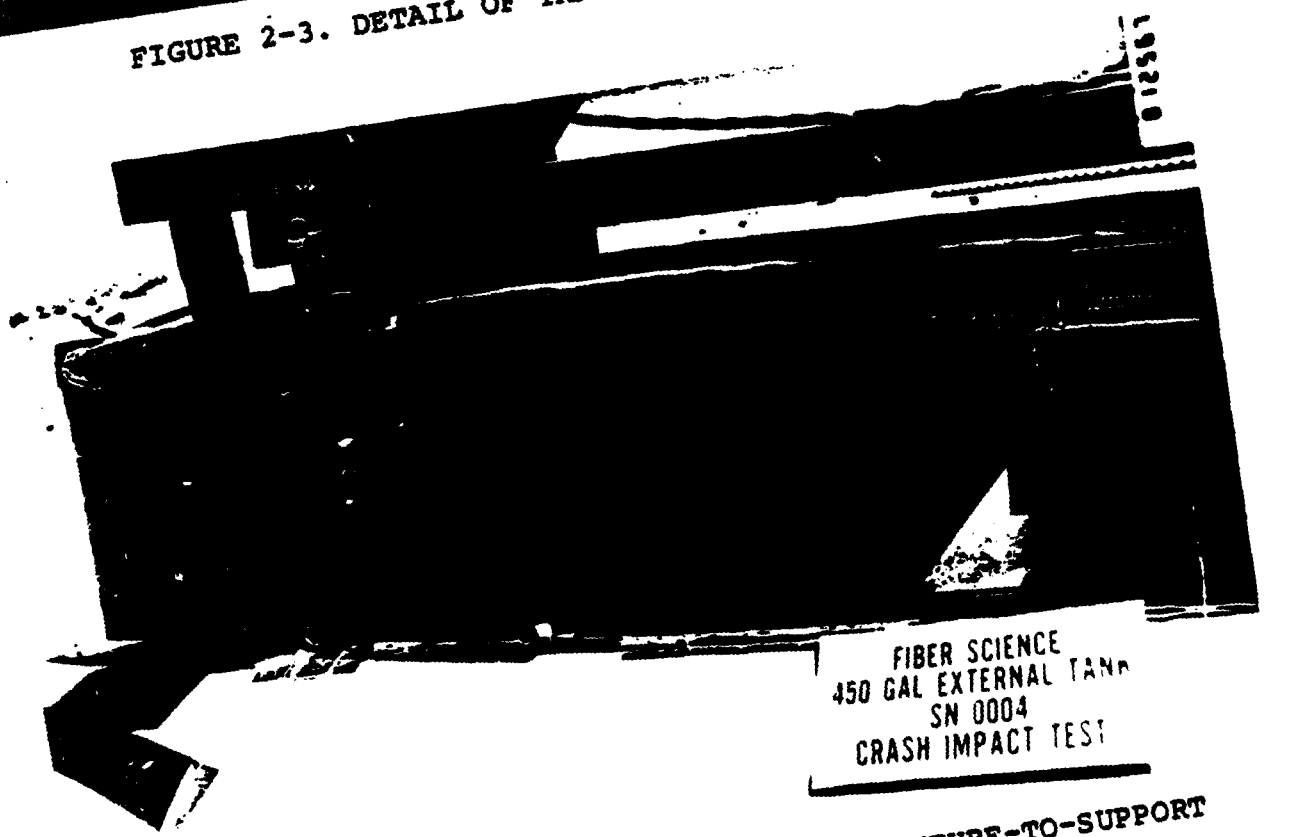


FIGURE 2-4. PYLON-TO-QUALIFICATION TEST FIXTURE-TO-SUPPORT FRAMEWORK INTERFACE.

To release the tank and pylon assembly from the Qualification Test Fixture, the release mechanism of the pylon assembly was utilized, fired by a combination of one ARD 863-1 and one ARD 446-1 cartridge. To avoid a forced ejection, the stainless steel gas flow line leading to the ejection piston was disconnected at the piston fitting. The line was not capped, allowing the gas to vent after operating the hook assembly mechanism. The ejection cartridges were activated by a 28 volt manually operated firing system designed by Dynamic Science. Immediately prior to the test, the ejection cartridges were installed through the pylon access opening (Figure 2-5).

The crane speed at release was measured by the fifth wheel assembly described in Table 2-1. The speed was locked when the cartridges were fired. The drop height was set and measured prior to the test run.

For a period of five minutes after impact, spilled fluid was collected in catch pans and on the surface of plastic sheets. The fluid collected from all ruptures was stored in a bucket and measured later using both a graduated cylinder and scales. For fluid which could not be collected, the size and depth of the pool on the asphalt was measured and recorded.

2.2.2 Electronic Data Acquisition

The electronic data obtained in these tests consisted of external surface strains, internal pressures, and, in one test, accelerations. The strain gages were bonded with Eastman 910 Adhesive to smooth sanded areas of the outer layer of circumferential glass/epoxy windings. The pressure transducers were, in general, screwed into threaded holes in the access covers. Figures 2-6 and 2-7 show typical strain gage and pressure transducer mountings on the tank. The exact transducer locations for each test are described in following sections.

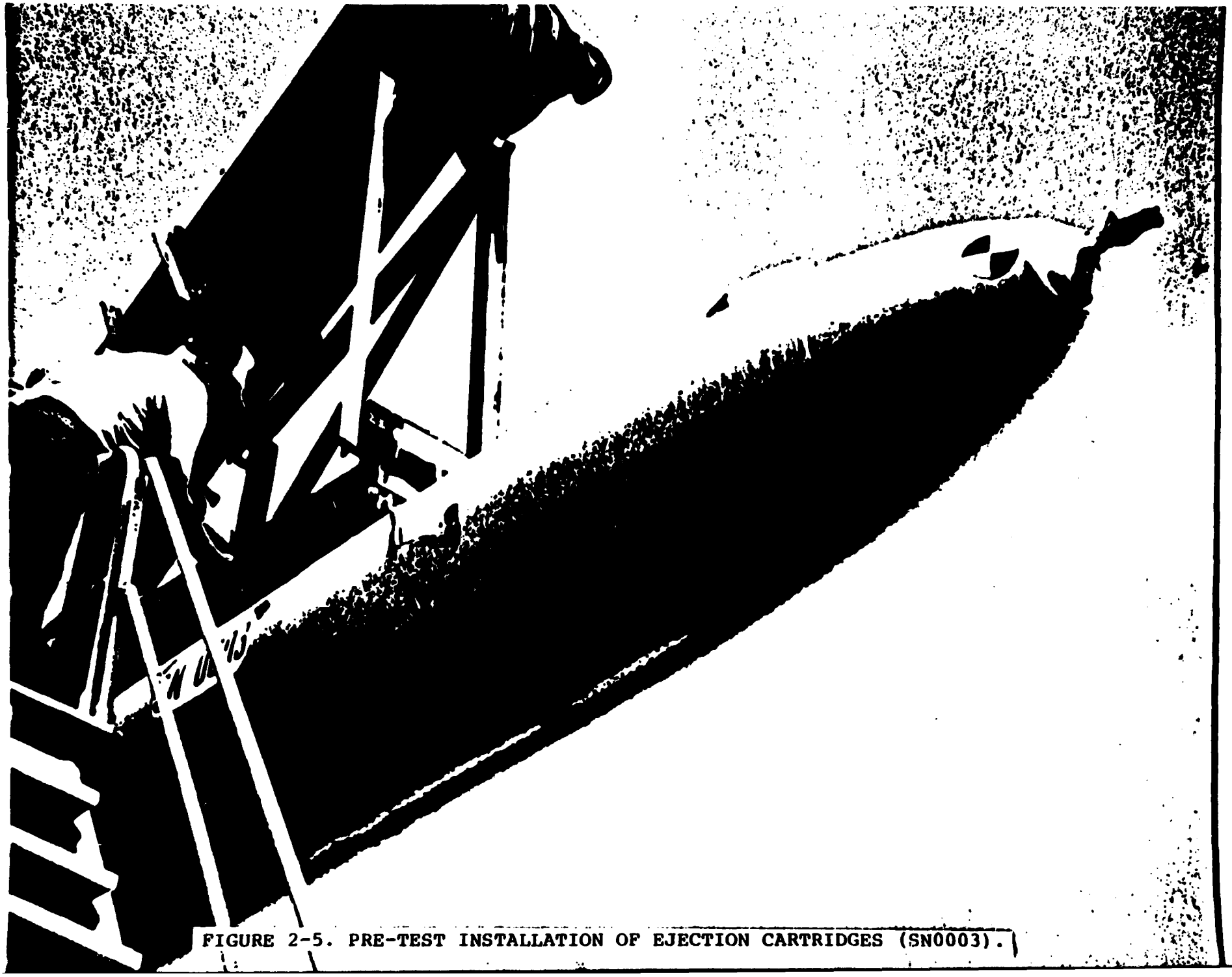


FIGURE 2-5. PRE-TEST INSTALLATION OF EJECTION CARTRIDGES (SN0003).

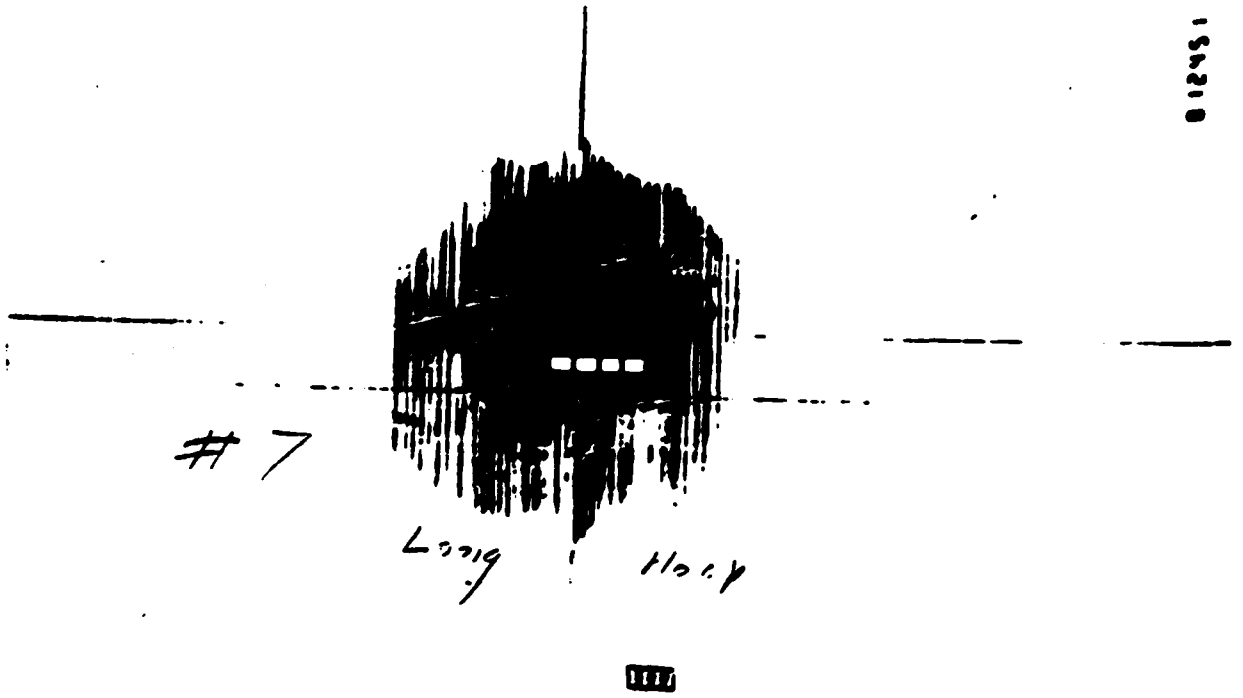


FIGURE 2-6. TYPICAL STRAIN GAGE MOUNTING ON TANK EXTERIOR.

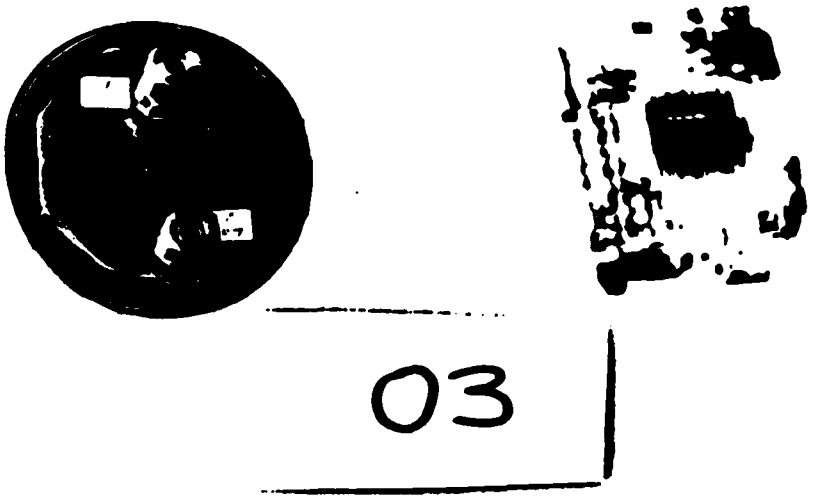


FIGURE 2-7. TYPICAL MOUNTING OF PRESSURE TRANSDUCERS THROUGH ACCESS COVER.

The individual transducers and the components of the data acquisition system are described in Table 2-1. Each transducer on the fuel tank was attached to an Ectron differential amplifier within the Remote Signal Conditioning Module (RSCM) mainframe by an umbilical cable. The transducer signals after amplification were converted to the frequency domain by the Voltage Controlled Oscillators in the RSCM mainframe. The information was then multiplexed and transmitted by telemetry to the Sabre III instrumentation tape recorder for recording.

The recorded, multiplexed signal was later played back and demodulated by the Data Control Systems demodulator. The demodulated signal was then filtered and digitized for processing and plotting on the Data General S130 Eclipse computer.

2.2.3 Photographic Coverage

Each crash test was recorded on 16 mm color film by four cameras. The event was filmed at 24 fps, 400 fps, and 1000 fps. In addition, a complete set of 35 mm color slides was taken of each test.

2.3 TEST RESULTS

Table 2-2 presents a brief summary of the results of the three tests, based strictly on leakage.

TABLE 2-2. SUMMARY OF TEST RESULTS

Tank Serial No.	Forward Velocity	Vertical Velocity	Leakage	Pass/Fail
0003	N/A	N/A	≈450 Gal/Min	Invalid Test
0004	39.3 Ft/Sec	35.5 Ft/Sec	>3000 cc/Min	Fail
0002	32.3 Ft/Sec	32.1 Ft/Sec	≈40 Gal/Min	Fail

N/A = Not Available

Based on the results of the tests involving Tanks SN0004 and SN0002, this tank design fails to meet the requirements of Paragraph 3.4.1.7.5 of Technical Exhibit ASD/ENFEA-78, October 1978.

3.0 TEST DATA

3.1 TEST T3-1, TANK SERIAL NUMBER 0003

3.1.1 Test Conditions, SN0003

Prior to the test, a steel framework was affixed to the crane boom. The Qualification Test Fixture, as received from Fiber Science, was attached to the steel framework. The tank was instrumented as recorded in Table 3-1.

On the day of the test, motion picture cameras were set up at the test site as recorded in Table 3-2. The tank and pylon were affixed to the Qualification Test Fixture using the mounting hooks of the pylon. The crane was then driven to the test site. The crane boom was raised until the tank was in a 2° nose-down position, and the tank was filled with colored water through the aft filler access until the water began to overflow. Per previous directions from Fiber Science, the boom was then lowered until the tank was in a 2° nose-up position, in order to better ensure an impact angle between 0° and 15° nose-up. By extending and retracting the crane boom, the proper initial height of the tank was achieved. Figure 3-1 shows tank SN0003 in its pre-test configuration. The ARD 863-1 and ARD 446-1 cartridges were installed, pre-test approval was obtained (Data Sheet 1), and the crane was backed up to the starting point.

A summary of test conditions is presented in Table 3-3.

3.1.2 Test Results, SN0003

After a crane run of approximately 1700 feet, the ejection cartridges were fired at the test site to release the pylon mounting hooks. The tank and pylon did not release from the Qualification Test Fixture.

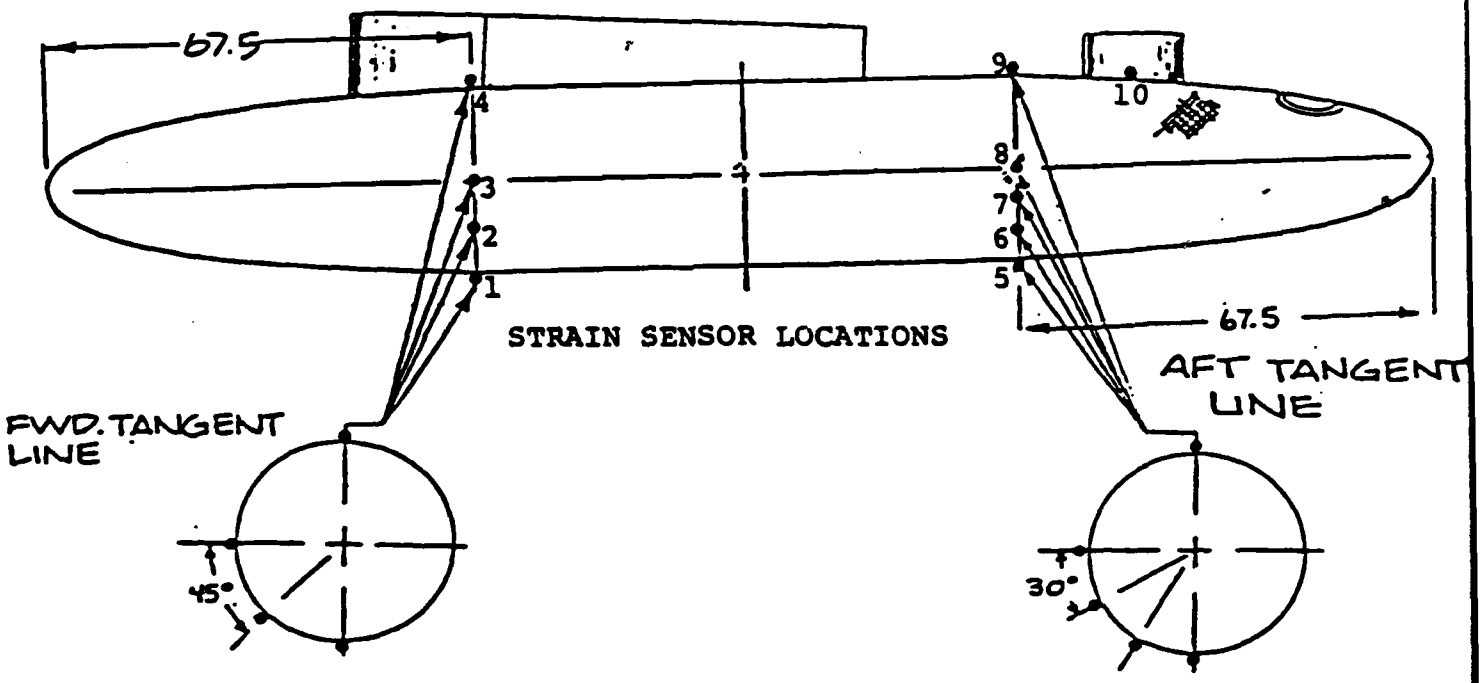
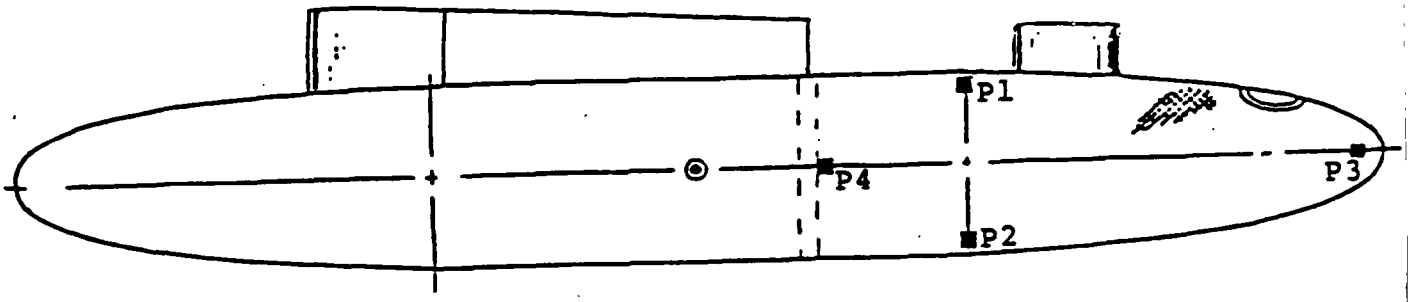


TABLE 3-1. CRASH IMPACT TEST INSTRUMENTATION - SN0003

STRAIN GAGE LOCATIONS		EXPECTED RANGES	
No.	Description of Location	Long. micro in./in.	Hoop micro in./in.
1	Fwd. Tangent, Bottom ℄	12.5 K	22.0 K
2	Fwd. Tangent, 45° Up Left Side from Bottom ℄	12.5 K	30.0 K
3	Fwd. Tangent, Left Side ℄	12.5 K	20.0 K
4	Fwd. Tangent, Top ℄	12.5 K	10.0 K
5	Aft Tangent, Bottom ℄	12.5 K	22.0 K
6	Aft Tangent, 30° Up Left Side from Bottom ℄	12.5 K	30.0 K
7	Aft Tangent, 60° Up Left Side from Bottom ℄	12.5 K	30.0 K
8	Aft Tangent, Left Side ℄	12.5 K	20.0 K
9	Aft Tangent, Top ℄	12.5 K	10.0 K
10	Between Fuel and Air Fittings, Top ℄	12.5 K	10.0 K



PRESSURE SENSOR LOCATIONS

TABLE 3-1. CRASH IMPACT TEST INSTRUMENTATION - SN0003 (CONTD).

PRESSURE SENSOR LOCATIONS		EXPECTED RANGES
No.	Description of Location	PSIA
P1	Through Aft Access Cover, Measures 2" Below Top $\mathbb{Q}_L$	650-700
P2	Through Aft Access Cover, Measures 2" Above Bottom $\mathbb{Q}_L$	650-700
P3	Through Tail Hole, Measures 2" Forward of Tail $\mathbb{Q}_L$	650-700
P4	Through Aft Baffle Access Cover, Measures at Tank $\mathbb{Q}_L$	650-700

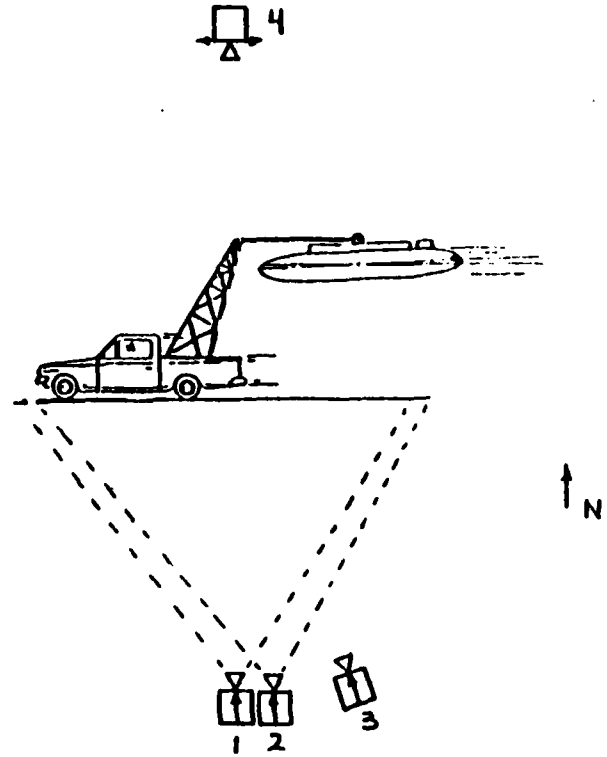
Test No: T3-1 Test Date: May 8, 1981

Test Type: Fuel Tank Crash Impact Test

Vehicle A: Crane With Fuel Tank

Vehicle B:

Comments: Qualification Test for Fiber Science
450 Gallon H-53 Helicopter External Tank



CAMERA	YES
STILLS	
SLIDES	x
MOVIE	x
POLAROID	
VIDEO	

CAMERA SYMBOLS

- PIT
- GROUND
- BARRIER
- OVERHEAD
- ON-BOARD
- PANNING

FRAME RATE

1. 1000 fr/sec
2. 200 fr/sec
3. Other 24 fr/sec
4. 400 fr/sec
5. 500 fr/sec

Loc. No.	Location	Field of View	Lens Size	Nom. Frm Rate	Tim-ing (Hz)	Impact Dist-X	C.L. Dist-Y	CAM Hght-Z
1	South Side	Overall View of Crash Site	16 mm	1	99			
2	South Side	Redundant for Camera 1	15 mm	1	100			
3	South Side	Close-up View of Tank During Crash Sequence*	43 mm	4	100			
4	North Side	Panning - Test and Results*	-	3	-			
		*Views included in test film.						

DSI FORM NO. TSO 125

TABLE 3-2. PHOTOGRAPHIC COVERAGE - SN0003.

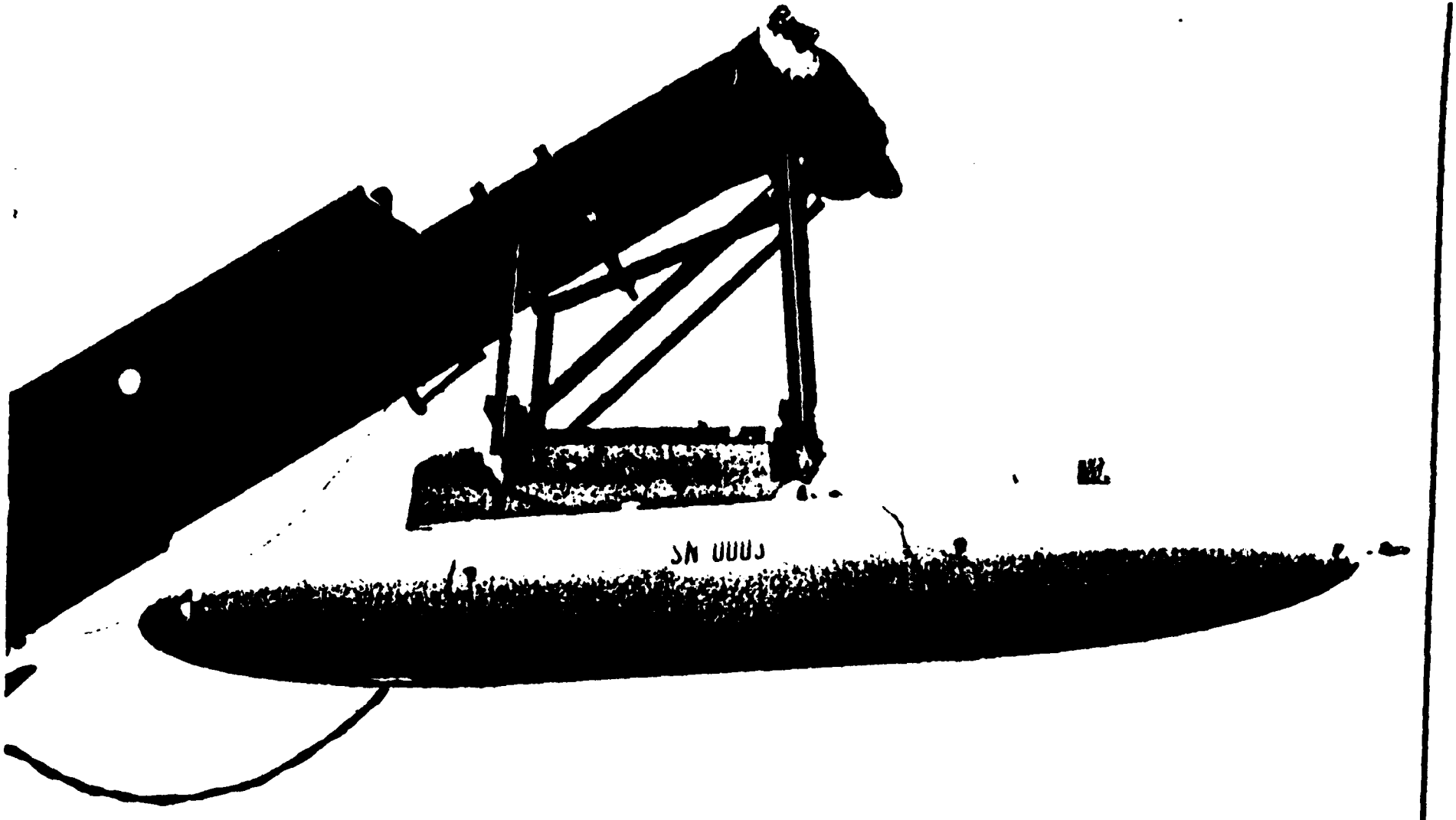


FIGURE 3-1. PRE-TEST FUEL TANK SN0003 ATTACHED TO CRANE.

DATA SHEET 1. PRE-CRASH IMPACT EXAMINATION - TANK SN0003

Testing Activity: Dynamic Science, Inc.

Tank Serial No: 0003

Test Date: May 8, 1981

Activity Test Engineer: Terry Bjork

F.S.I. Test Engineer: Richard R. Lyman

Government Representive: Hugh Hilliard

EXAMINATION OF PRODUCT:

Visual Inspection: Approved

Delaminations (Tap Test): No delaminations noted during test.

MOUNTING:

Aircraft Simulated Attachment Deviations If Any: No use of fuel and air fittings or aft pylon fairing. Fuel and air access plugged with machined aluminum plugs. Tank mounted at 2° nose-up per Fiber Science instructions.

ARRANGEMENT:

Approved Test Arrangement:

Testing Activity Approval

Approved By Terry B. E Date 5-8-81

F.S.I. Test Engineer Approval

Approved By Richard R. Lyman Date 8 May 81

Government Approval

Approved By Hugh Hilliard Date 8 May 81

Minimum of two signatures required.

TABLE 3-3. CRASH IMPACT TEST SUMMARY - TANK SN0003

Test Description: FSI 450 Gallon Tank Crash Impact Qualification Test

Tank Serial Number: 0003 Mfg. Date: April 1981

Test Number: T3-1

Number of Data Channels: 24

Number of Cameras: 4

Date: May 8, 1981 Time: 9:53 AM Temperature: 78°F

PRE-TEST DATA

Tank Empty Weight: 347.6 pounds
Target Horizontal Velocity: 39.2 ± 2.0 ft/sec
Target Vertical Velocity: 35.3 ± 2.0 ft/sec
Drop Height: 19'6.3"
Drop Attitude: 2° Nose-Up
Amount Water Introduced*: 405 Gallons

POST-TEST DATA

Impact Attitude: Unknown
Actual Horizontal/Velocity: Unknown
Actual Vertical Velocity: Unknown
Number of Ruptures: 3
Leakage (Maximum Allowable = 1000 cc/min.): ≈450 gal./min.
Pass/Fail: Invalid Test

*Based on pre- and post-filling weights of water wagon.

Some 350 feet downrange, the crane appeared to hit a bump on the asphalt and the rear pylon hooks released. The rear of the tank rotated downward while the front pylon hooks were still attached to the Qualification Test Fixture. When the front pylon hooks finally did release, the tank continued to rotate further nose-up until impact.

Unfortunately, all cameras had either run out of film or had been turned off prior to impact so that there is no record of impact angle or crash events. From visual observations at the time, the impact angle seemed to be nearly 90° nose-up. What film exists suggests that the tank was well on its way to such an attitude. In addition, the speed indicator had been locked at the moment the ejection cartridges were fired, so there is no record of the forward velocity. The crane driver did indicate that he had slowed only minimally from the impact site. The instrumentation tape recorder was still running, and the strain and pressure data from this test was obtained.

Once again from visual observations, the tank seemed to buckle and nearly break in half upon impact. The resulting spray of water obscured the rest of the event. Figure 3-2 shows the tank shortly after impact. Nearly all water was drained from the tank by the time the observers reached the impact site, shown in Figure 3-3. The tank came to rest 55'6" from initial impact point.

Because the impact angle was so severe and because of the unknown rotational velocity, this test was obviously not a valid test of the fuel tank's integrity.

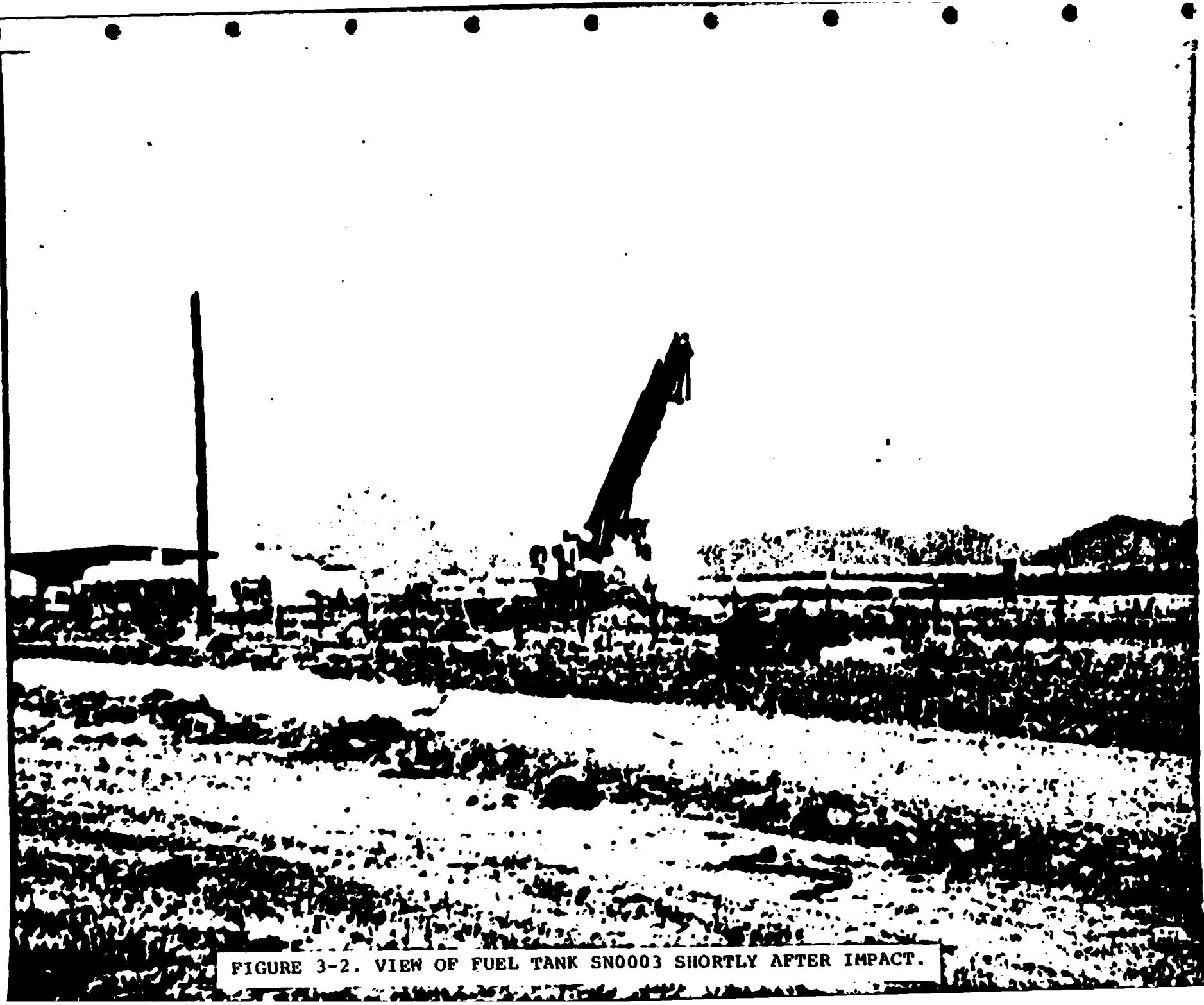


FIGURE 3-2. VIEW OF FUEL TANK SN0003 SHORTLY AFTER IMPACT.

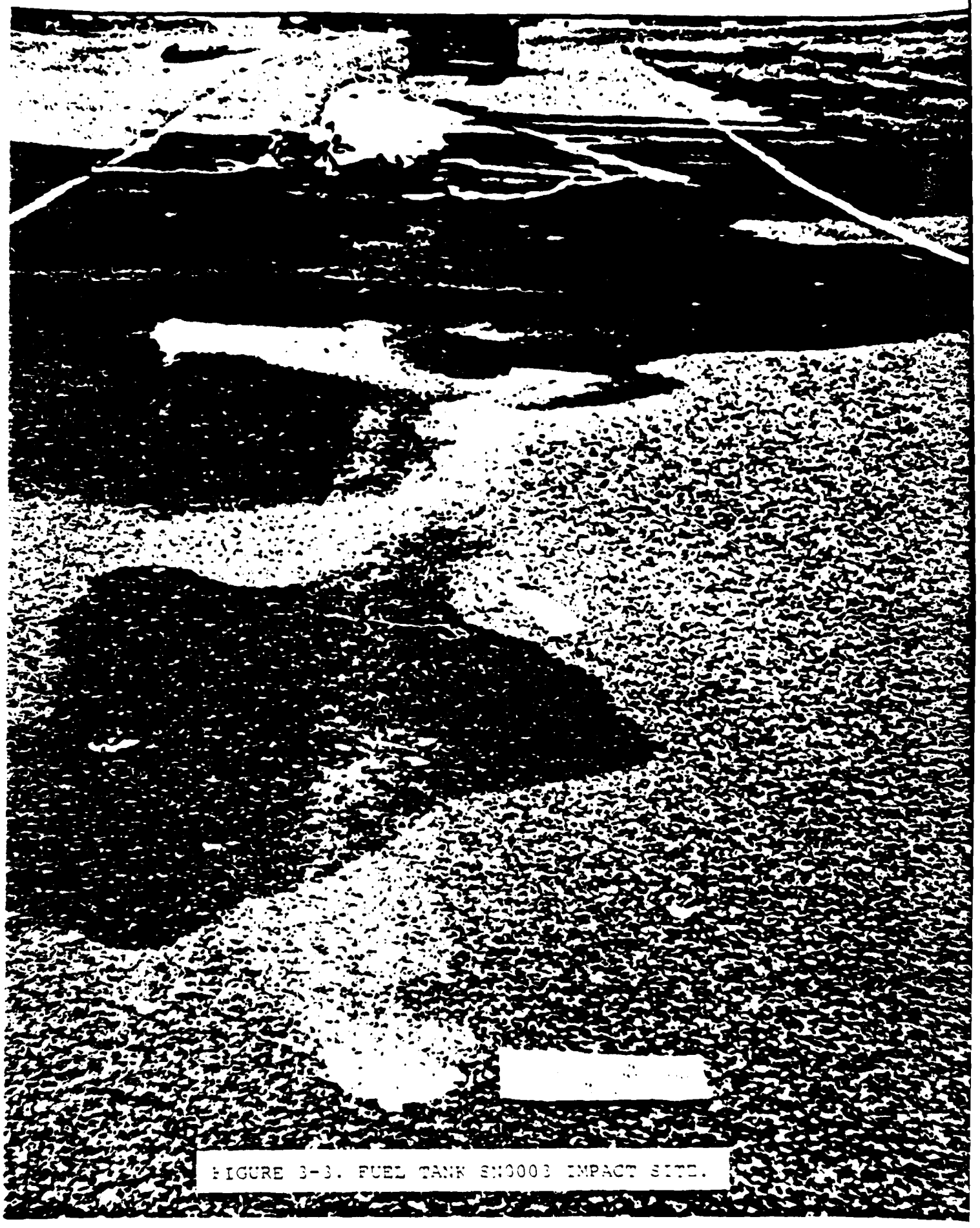


FIGURE 3-3. FUEL TANK SN0003 IMPACT SITE.

It was determined that the cause of the failure to release was an improper Qualification Test Fixture-to-pylon hook assembly interface. The design of the Qualification Test Fixture placed the support point of the fixture directly over the pivot point of the hook assembly creating an equilibrium state. In addition, the inside edges of the fixture support points were perfectly square, which could have prevented the hooks from sliding out, even if a moment was present on the hook assembly arms. It was decided that the Qualification Test Fixture would be modified prior to the next test.

3.1.2.1 Tank Damage and Electronic Data, SN0003

The damage to the tank is described in the text, damage sketches, and photographs of Data Sheet 2. The electronic data are presented as a series of computer generated plots in Appendix B.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0003

GENERAL APPEARANCE:

Although the tank did not separate in pieces, its overall post-test appearance is poor. There is a significant circumferential rupture behind the pylon over the top of the tank. The nose cap is partially extruded from the front of the tank, there are jagged fractures on the underside of the tank nose and tail (the front is also partially ruptured), and there are several shallow fractures around the tank forward of the pylon. The tail cap is destroyed. However, it should be noted that a pressure transducer was cantilevered out of the end cap, approximately 6 inches beyond the end of the tank, and, due to the impact attitude, was the first object to contact the ground. This no doubt exaggerated the damage to the tail cap. Surface damage includes severe scuffing on the bottom and left side of the tank.

Figure 3-4 presents a scaled sketch of non-rupture fractures and other surface damage. Figures 3-5 through 3-7 show the tank in its post-test rest position. Figure 3-8 shows the tank after being righted. Figures 3-9 and 3-10 show the nose and tail cap respectively.

LEAKAGE:

Leakage not collected. Nearly entire contents of tank drained within one minute.

RUPTURES

Three rupture locations were noted. Figure 3-11 is a scaled sketch of the rupture locations.

Locations

1. Approximately 8.0' forward of tank center point on bottom.
2. Approximately 3.0' aft of tank center point around top of tank.
3. Approximately 9.0' aft of tank center point on tip of tail.

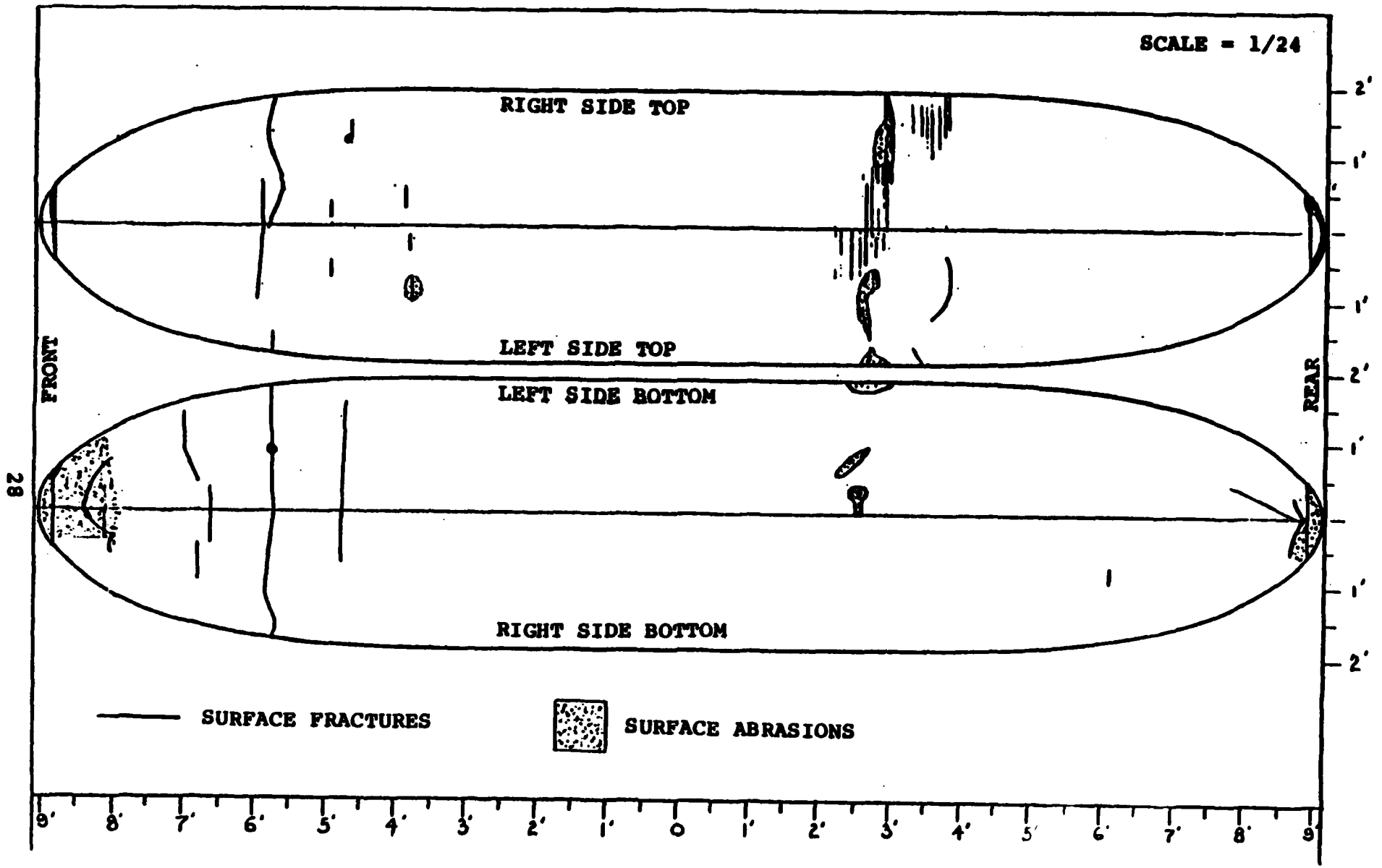
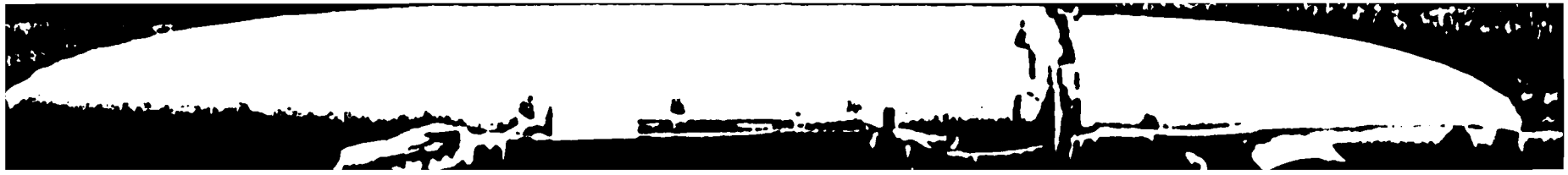


FIGURE 3-4. FUEL TANK SN0003 NON-RUPTURE SURFACE DAMAGE SKETCH.

FIGURE 3-6. FUEL TANK SN0003 POST-TEST FRONT VIEW.



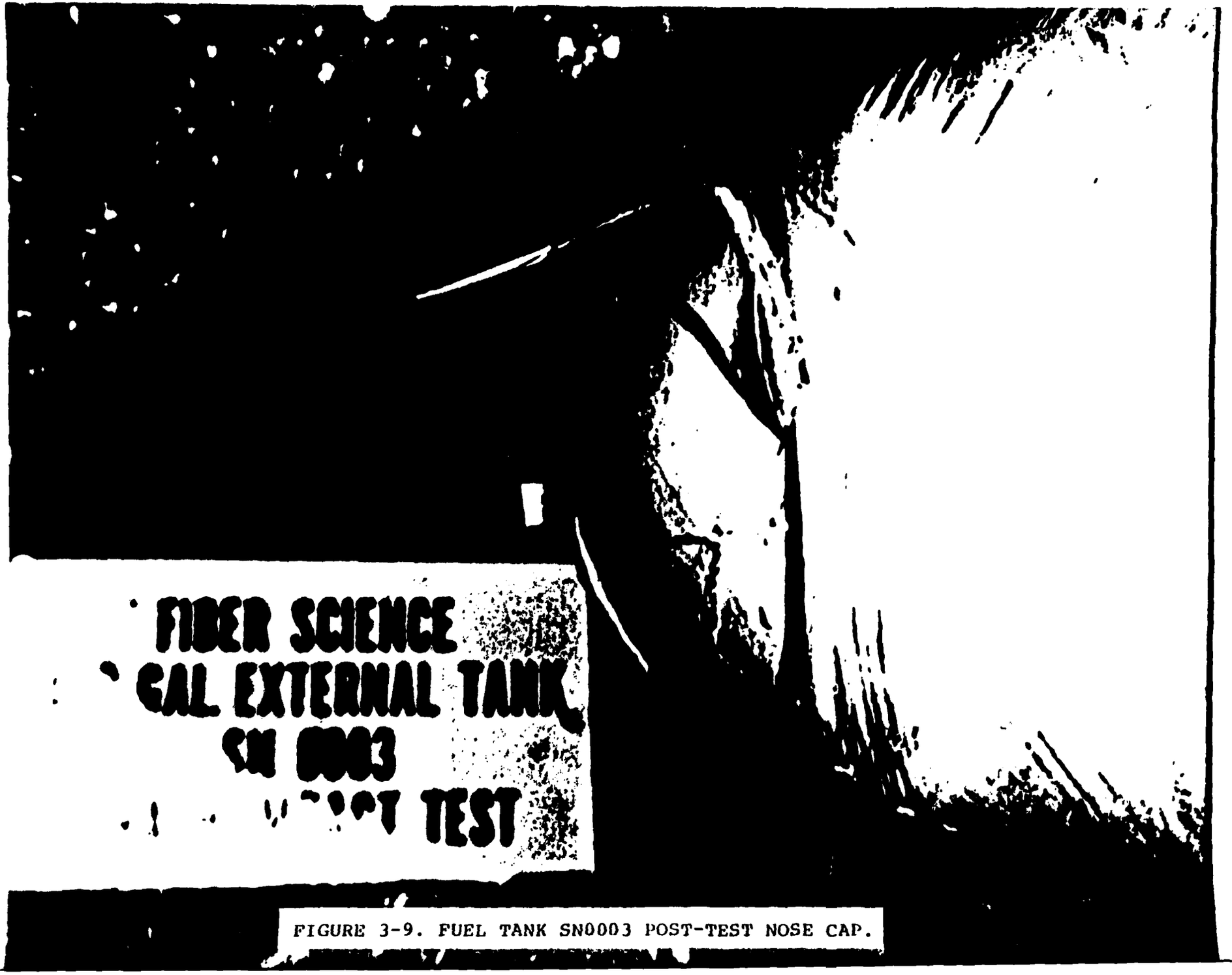


FIGURE 3-9. FUEL TANK SN0003 POST-TEST NOSE CAP.

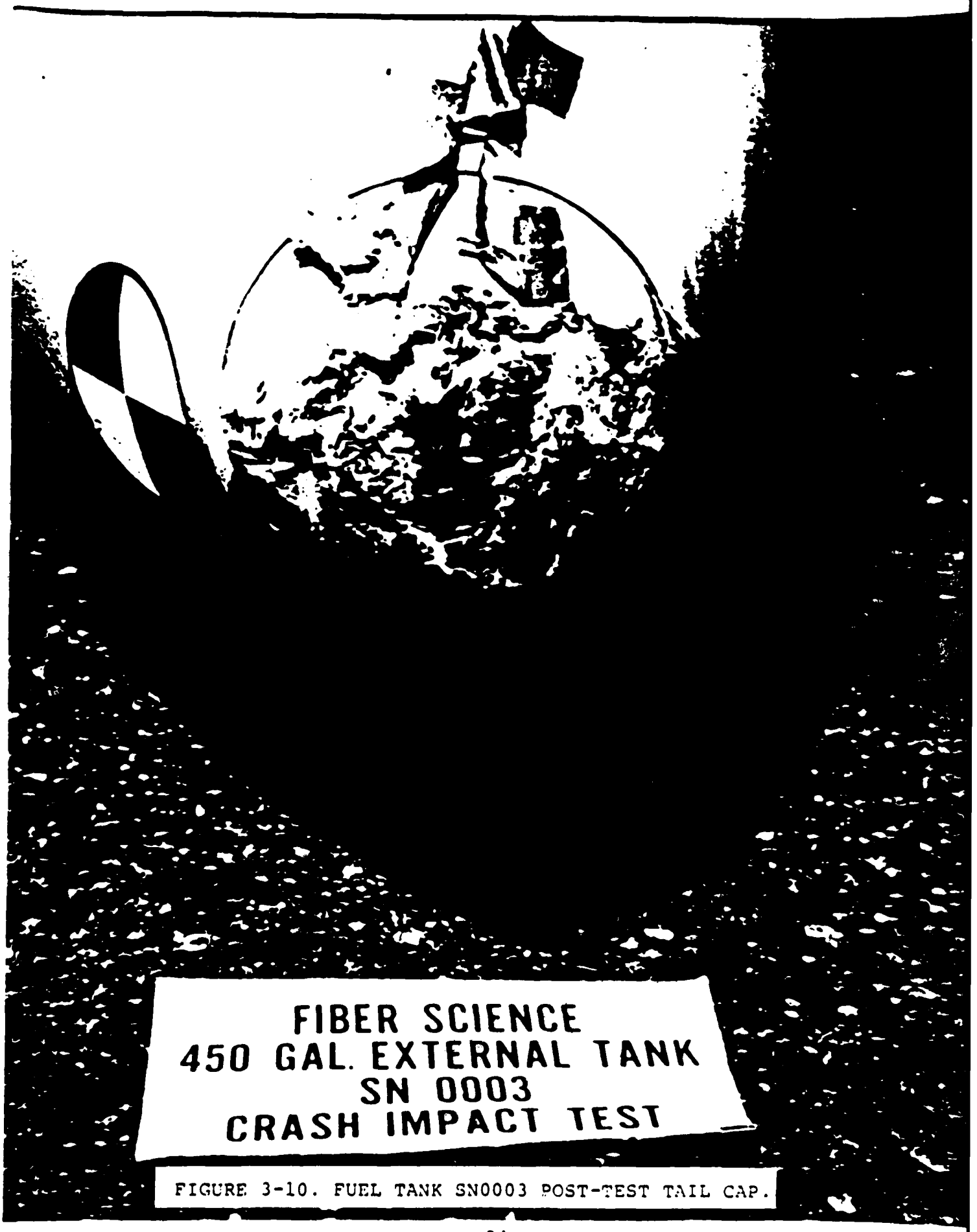


FIGURE 3-10. FUEL TANK SN0003 POST-TEST TAIL CAP.

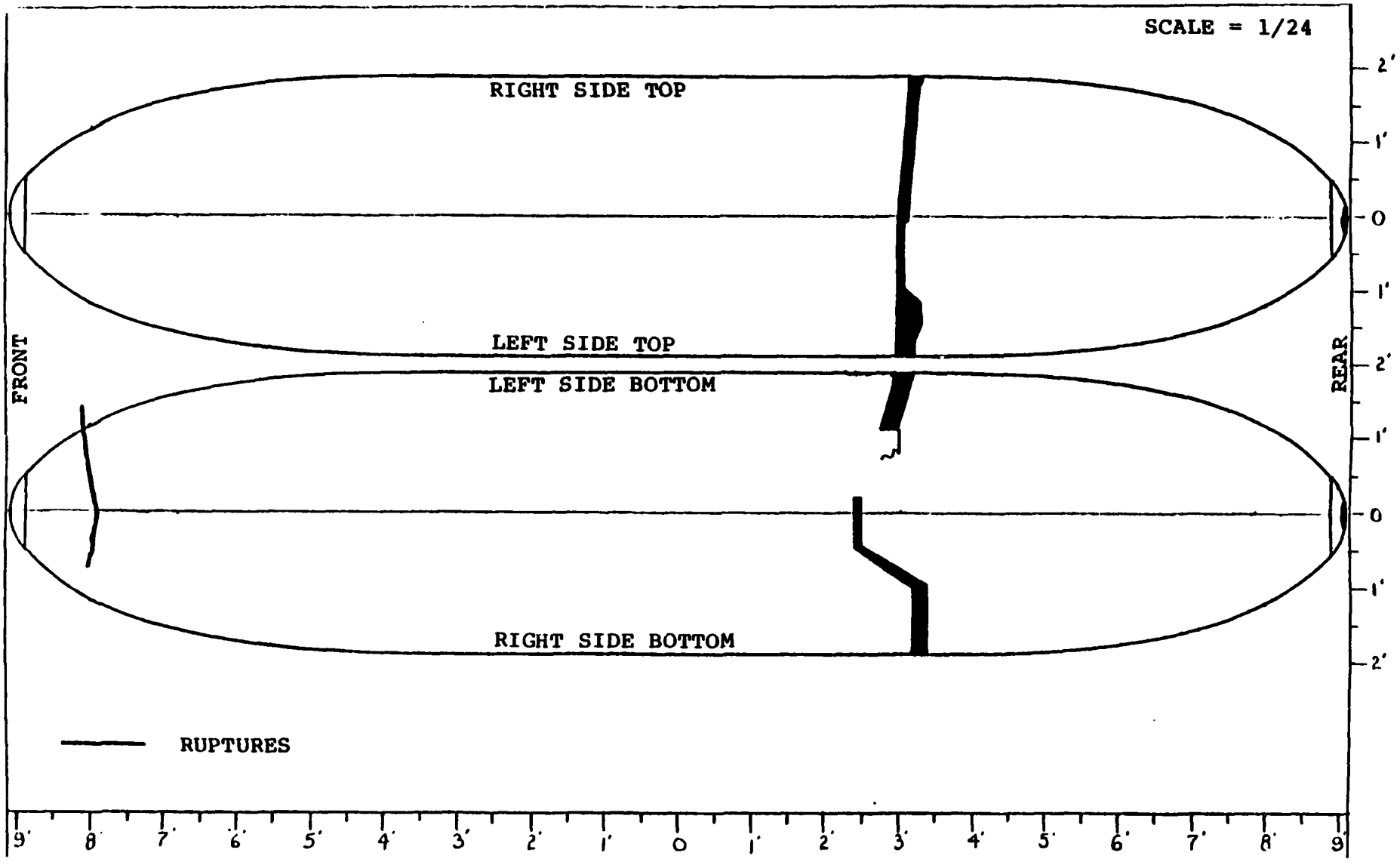


FIGURE 3-11. FUEL TANK SN0003 RUPTURE LOCATION SKETCH.

Extent of Damage (Ruptures)

1. Jagged tearing failure of helical windings at front underside of tank. All layers down to thermoplastic exposed. Rupture extends approximately one-half tank circumference.

2. Complete split of tank around seven-eighths of circumference. All layers exposed. Pieces of honeycomb and thermoplastic protruding to surface. Primarily a failure of helical windings, but circumferential winding tear noted on right side. Rupture runs over top of tank. Severe damage to circumferential windings near rupture.

3. Rupture 3 is a hole in the tip of the tail cap, and may have been aggravated by the pressure sensor which was accessed through the tail cap. The material of the tail cap has suffered extensive compressive damage.

CRASH IMPACT IMPRINT

The impacted area of the tank includes both the bottom and left side of the tank. Majority of damage aside from ruptures and fractures consists of scuffing which exposed the yellow primer paint and circumferential windings. Near the drain plug and along the left side there are deeper scuffs exposing the graphite windings. On left side of tank, approximately even with the front of the pylon, there is a deep scuff down to helical glass/epoxy windings. Near the primary rupture there are several surface delaminations.

Figure 3-12 is a scaled sketch of the entire impact area.

OTHER DAMAGE

Final Distortion of Cross Sectional Shape

Not measured.

End Closures

Nose Cap - Partially extruded out from front of tank.

Tail Cap - Destroyed. Various layers of material separated.

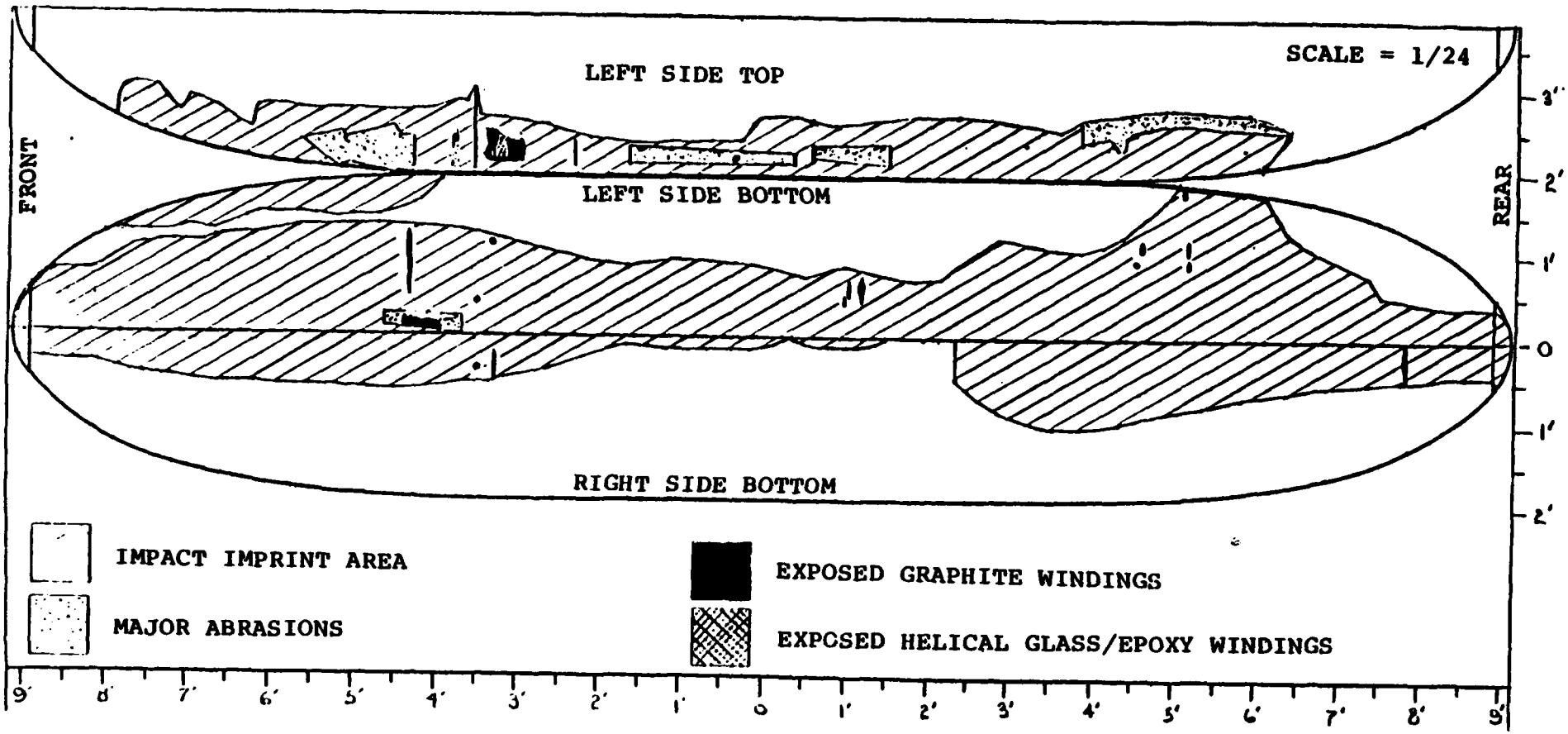


FIGURE 3-12. FUEL TANK SN0003 IMPACT IMPRINT SKETCH.

(TO BE COMPLETED BY FIBER SCIENCE)

Ref. Para. 4.7.4: DELAMINATIONS

Results of Tap Test for Delaminations

"REFER TO TEST REPORT"

(Supply scaled sketch of size, location and approximate shape).

Ref. Para. 4.7.7 DISSECTION OF THE TANK

Approved By_____ Date_____

Condition of Frames

Condition of Probe

Condition of Float Switches

Condition of Fuel Line

(TO BE COMPLETED BY FIBER SCIENCE)

EVALUATION OF DATA

CAMERAS: "REFER TO TEST REPORT"

PRESSURE RECORDINGS:

STRAIN RECORDINGS:

3.2 TEST T3-2, TANK SERIAL NUMBER 0004

3.2.1 Test Conditions, SN0004

As a result of the release system failure in the previous test, the Qualification Test Fixture was modified per Fiber Science instructions in order to ensure a proper release. Each of the four Fixture support points was moved outward 1/16-inch in order to provide a moment on the pylon hook assembly arms. In addition, the inside edge of each support point was chamfered to lessen the possibility of the pylon hooks catching on the square edges. Finally, just prior to mounting the tank on the Fixture, the support points were lubricated with Molydisulfide.

In addition to the problem encountered with the release system in the previous test, it was noted that only 405 gallons of water had been introduced into Tank SN0003. The cause for this shortage was determined to be a lack of air vents at the top of the tank's internal baffles. In order to provide venting for the trapped air, one of the bolts at the top of each baffle was removed.

In the previous test, when the tank landed on its tail cap, the pressure sensor at this location was destroyed. The tail cap instrumentation was deleted for the test of SN0004. Instrumentation for this test is recorded in Table 3-4.

The balance of test conditions for this test were the same as for the previous test. Table 3-5 documents photographic coverage. Table 3-6 presents a summary of test conditions. Figure 3-13 shows the tank in its pre-test attitude. Data Sheet 1 documents pre-test approval.

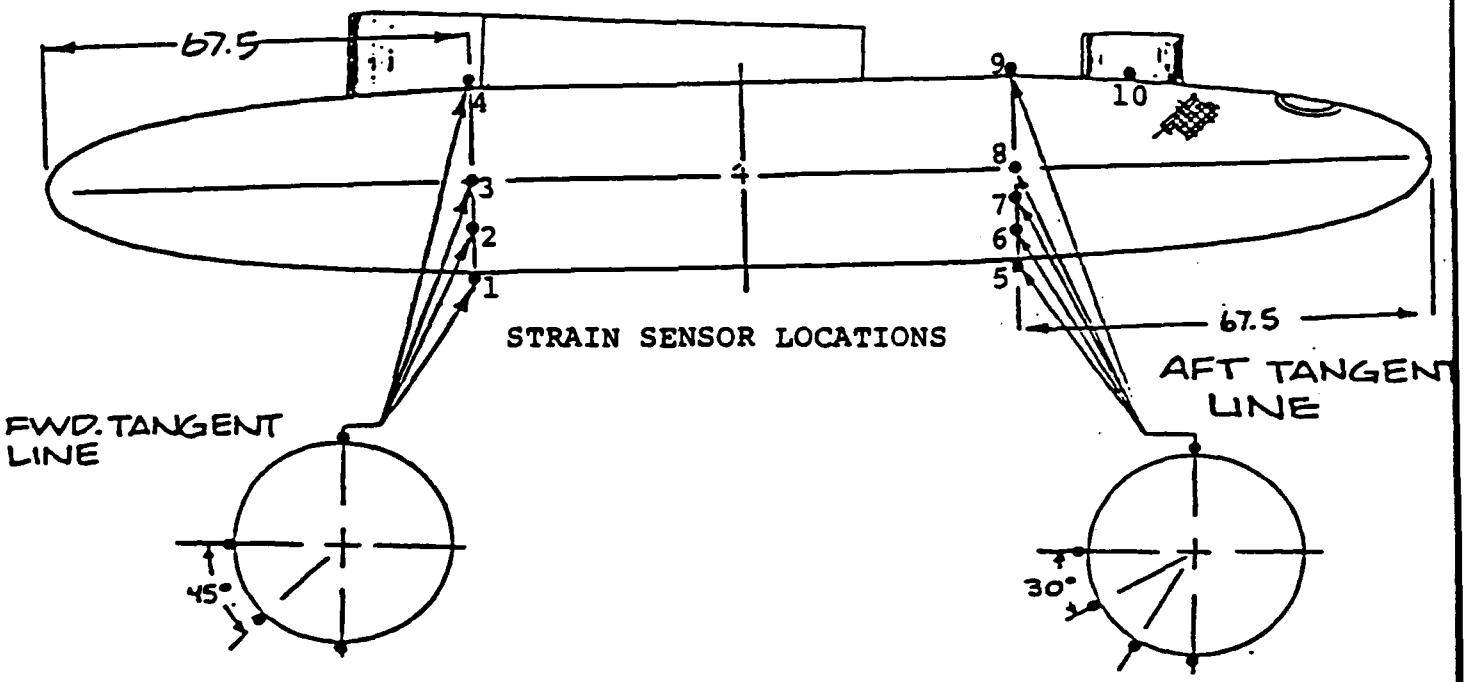
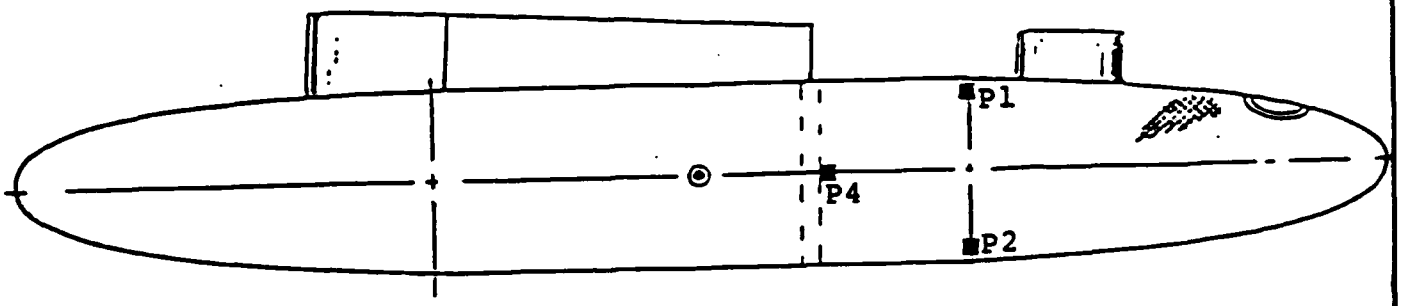


TABLE 3-4. CRASH IMPACT TEST INSTRUMENTATION - SN0004

STRAIN GAGE LOCATIONS		EXPECTED RANGES	
No.	Description of Location	Long. micro in./in.	Hoop micro in./in.
1	Fwd. Tangent, Bottom ℄	12.5 K	22.0 K
2	Fwd. Tangent, 45° Up Left Side from Bottom ℄	12.5 K	30.0 K
3	Fwd. Tangent, Left Side ℄	12.5 K	20.0 K
4	Fwd. Tangent, Top ℄	12.5 K	10.0 K
5	Aft Tangent, Bottom ℄	12.5 K	22.0 K
6	Aft Tangent, 30° Up Left Side from Bottom ℄	12.5 K	30.0 K
7	Aft Tangent, 60° Up Left Side from Bottom ℄	12.5 K	30.0 K
8	Aft Tangent, Left Side ℄	12.5 K	20.0 K
9	Aft Tangent, Top ℄	12.5 K	10.0 K
10	Between Fuel and Air Fittings, Top ℄	12.5 K	10.0 K



PRESSURE SENSOR LOCATIONS

TABLE 3-4. CRASH IMPACT TEST INSTRUMENTATION - SN0004 (CONTD).

PRESSURE SENSOR LOCATIONS		EXPECTED RANGES
No.	Description of Location	PSIA
P1	Through Aft Access Cover, 2" Below Top $\mathbb{C}_L$	650-700
P2	Through Aft Access Cover, Measures 2" Above Bottom $\mathbb{C}_L$	650-700
P4	Through Aft Baffle Access Cover, Measures at Tank $\mathbb{C}_L$	650-700

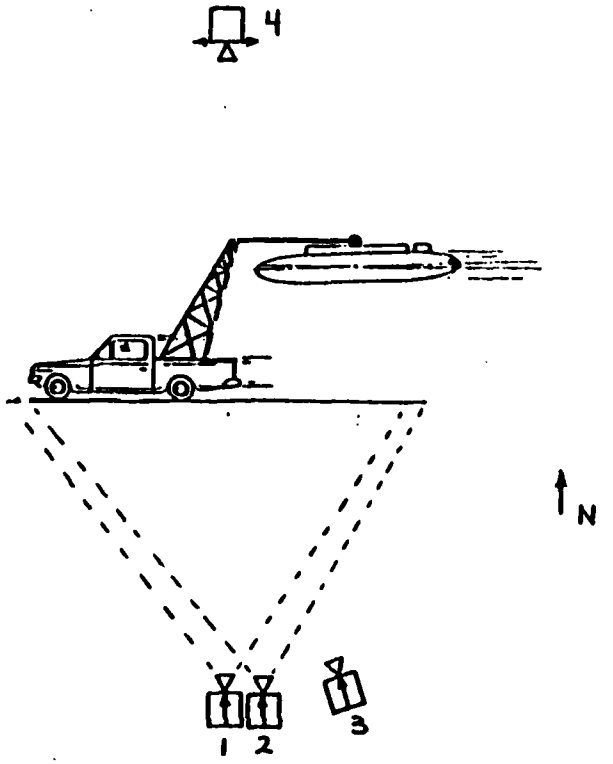
Test No: T3-2 Test Date: May 12, 1981

Test Type: Fuel Tank Crash Impact Test

Vehicle A: Crane With Fuel Tank

Vehicle B:

Comments: Qualification Test for Fiber Science
450 Gallon H-53 Helicopter External Tank



CAMERA	YES
STILLS	
SLIDES	x
MOVIE	x
POLAROID	
VIDEO	

CAMERA SYMBOLS

- PIT
- GROUND
- BARRIER
- OVERHEAD
- ON-BOARD
- PANNING

FRAME RATE

1. 1000 fr/sec
2. 200 fr/sec
3. Other 24 fr/sec
4. 400 fr/sec
5. 500 fr/sec

Loc. No.	Location	Field of View	Lens Size	Nom. Frm Rate	Timing (Hz)	Impact Dist-X	C.L. Dist-Y	CAM Hght-Z
1	South Side	Overall View of Crash Site	16 mm	1	99			
2	South Side	Redundant for Camera 1*	15 mm	1	101			
3	South Side	Close-up View of Tank During Crash Sequence*	43 mm	4	101			
4	North Side	Panning - Test and Results*	-	3	-			
		*Views included in test film.						

DSI FORM NO. TSO 125

TABLE 3-5. PHOTOGRAPHIC COVERAGE - SN0004.

TABLE 3-6. CRASH IMPACT TEST SUMMARY - TANK SN0004

Test Description: FSI 450 Gallon Tank Crash Impact Qualification Test

Tank Serial Number: 0004 Mfg. Date: April 1981

Test Number: T3-2

Number of Data Channels: 21

Number of Cameras: 4

Date: May 12, 1981 Time: 11:29 AM Temperature: 84°F

PRE-TEST DATA

Tank Empty Weight: 343.6 pounds
Target Horizontal Velocity: 39.2 ± 2.0 ft/sec
Target Vertical Velocity: 35.3 ± 2.0 ft/sec
Drop Height: 19'6.6"
Drop Attitude: 2° Nose-Up
Amount Water Introduced*: 421 gallons

POST-TEST DATA

Impact Attitude: 0.5° Nose-Up
Actual Horizontal Velocity: 39.3 ft/sec
Actual Vertical Velocity**: 35.7 ft/sec
Number of Ruptures: 4
Leakage (Maximum Allowable = 1000 cc/min.): >3000 cc/min.
Pass/Fail: Fail

*Based on pre- and post-filling weights of water wagon.
**Based on initial height and/or free-fall times from electronic data and high-speed films.

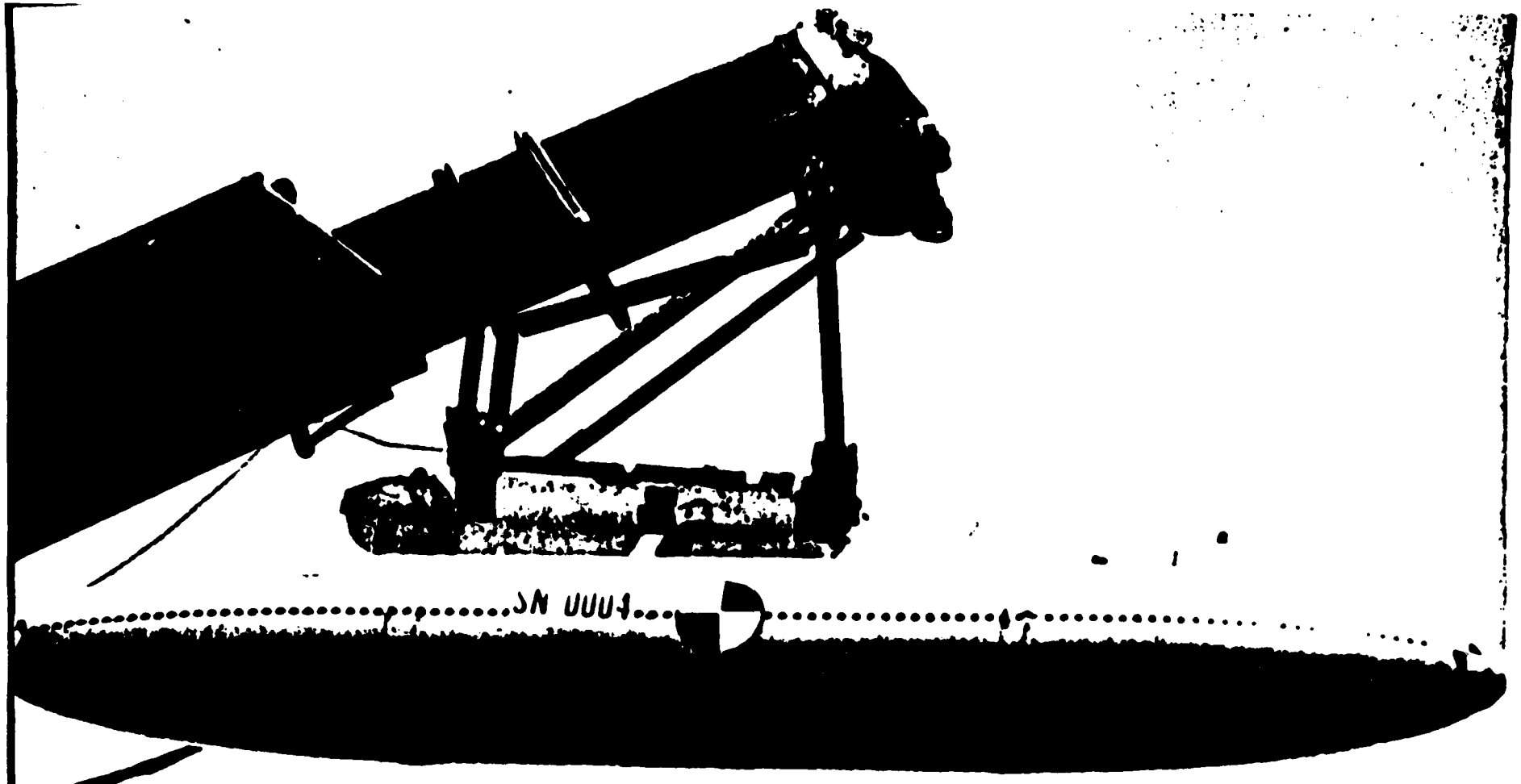


FIGURE 3-13. PRE-TEST VIEW OF FUEL TANK SN0004 ATTACHED TO CRANE.

DATA SHEET 1. PRE-CRASH IMPACT EXAMINATION - TANK SN0004

Testing Activity: Dynamic Science, Inc.

Tank Serial No.: 0004

Test Date: May 12, 1981

Activity Test Engineer: Terry Bjork

FSI Test Engineer: Richard R. Lyman

Government Representative: Hugh Hilliard

EXAMINATION OF PRODUCT:

Visual Inspection: Approved

Delaminations (Tap Test): No delaminations noted.

MOUNTING:

Aircraft Simulated Attachment Deviations If Any: No use of aft pylon fairing. Tank mounted at 2° nose-up per Fiber Science instructions.

INSTRUMENTATION:

Check Proper Operation:

1. Strain Gage 6X - Bad sensor, waived by FSI
2. Strain Gage 9Y - Bad sensor, waived by FSI

ARRANGEMENT:

Approved Test Arrangement:

Testing Activity Approval

Approved By Terry Bjork Date 5-12-81

F.S.I. Test Engineer Approval

Approved By Richard Lyman Date 12 May 81

Government Approval

Approved By Hugh Hilliard Date 12 May 81

Minimum of two signatures required.

3.2.2 Test Results, SN0004

When the ejection cartridges were fired, the tank and pylon released as desired and fell to the asphalt. When the tank had come to rest, leakage from the two major and two minor ruptures was collected for a period of five minutes and stored in a bucket for later measurement.

Analysis of the high-speed films showed that the tank impacted the ground at approximately 0.5° nose-up. Upon impact, the tank flattened substantially, and at least the two major ruptures were opened. The front of the tank began to rebound off the asphalt and the tank buckled severely behind the general area of the aft baffle. As the front of the tank continued upward, the tank regained its initial shape and continued its forward travel down the track in a nose-up attitude with the tail dragging on the asphalt. Figure 3-14 shows the tank at this point in the impact sequence.

The tank impacted the pavement a second time and flattened out again. After another rebound from the asphalt, the tank impacted the pavement a third time and skidded to a stop 66'3/4" from the initial impact point, coming to rest in an upright position, skewed slightly to the right. Figure 3-15 shows the impact site for Tank SN0004.

3.2.2.1 Tank Damage and Electronic Data, SN0004

The damage to the tank is described in the text, damage sketches, and photographs of Data Sheet 2. The electronic data are presented as a series of computer generated plots in Appendix C. Because the time interval between first and second impact was so great, the instrumentation data for the secondary and tertiary impacts was not obtained.

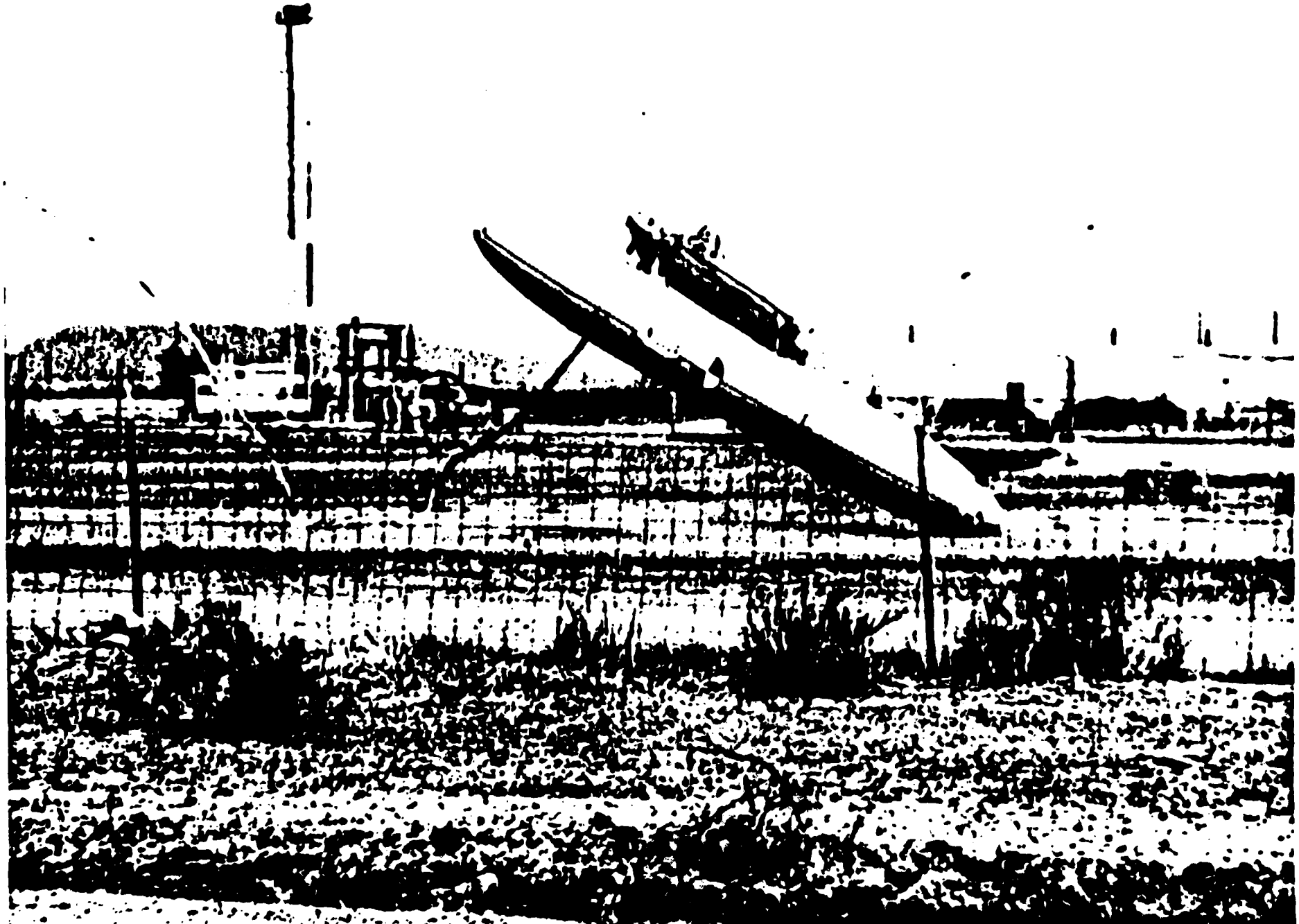


FIGURE 3-14. VIEW OF FUEL TANK SN0004 SHORTLY AFTER IMPACT.

FIGURE 3-15. FUEL TANK SN0004 IMPACT SITE.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0004

GENERAL APPEARANCE:

Overall post-test appearance is fairly good. Figures 3-16 and 3-17 show post-test views of the tank in its final rest position. Some "flattening" of the tank is evident.

There are some stress fractures on the top and sides of the tank. Additionally, there is a non-rupture circumferential fracture on the bottom of the tank towards the rear. At both the front and rear of the tank, on the bottom near the end caps, there are "V"-shaped stress fractures. Figure 3-18 is a scaled sketch of all tank surface non-rupture damage. Figures 3-19 and 3-20 show the "V"-shaped fractures at the front and rear of the tank, respectively.

From an overall standpoint, there appears to have been virtually no failure of circumferential windings. Nearly all failures occurred in the helical windings. The ruptures were all on the bottom surface of the tank.

LEAKAGE:

Total leakage in the first five minutes included 3.98 gallons collected and an unspecified amount on the asphalt in two major pools - 133" X 134" X 1/8" and 50' X 24" X 1/4". Most fluid collected from rupture designated 2 below, followed by rupture 3. Minor leakage from rupture 1 and trace leakage from rupture 4.

RUPTURES:

Four leakage locations were noted. Figure 3-21 is a scaled sketch of the rupture locations.

Locations

1. Approximately 6.5' forward of tank center point on bottom.
2. Approximately 4.5' forward of tank center point on bottom.
3. Approximately 3.5' aft of tank center point on bottom.
4. Approximately 5.5' aft of tank center point on bottom.

Figure 3-22 shows the forward underside of the tank including ruptures 1 and 2. Figure 3-23 shows the aft underside of the tank including ruptures 3 and 4. Figure 3-24 is a close-up view of rupture 2. Figure 3-25 is a close-up view of rupture 3.

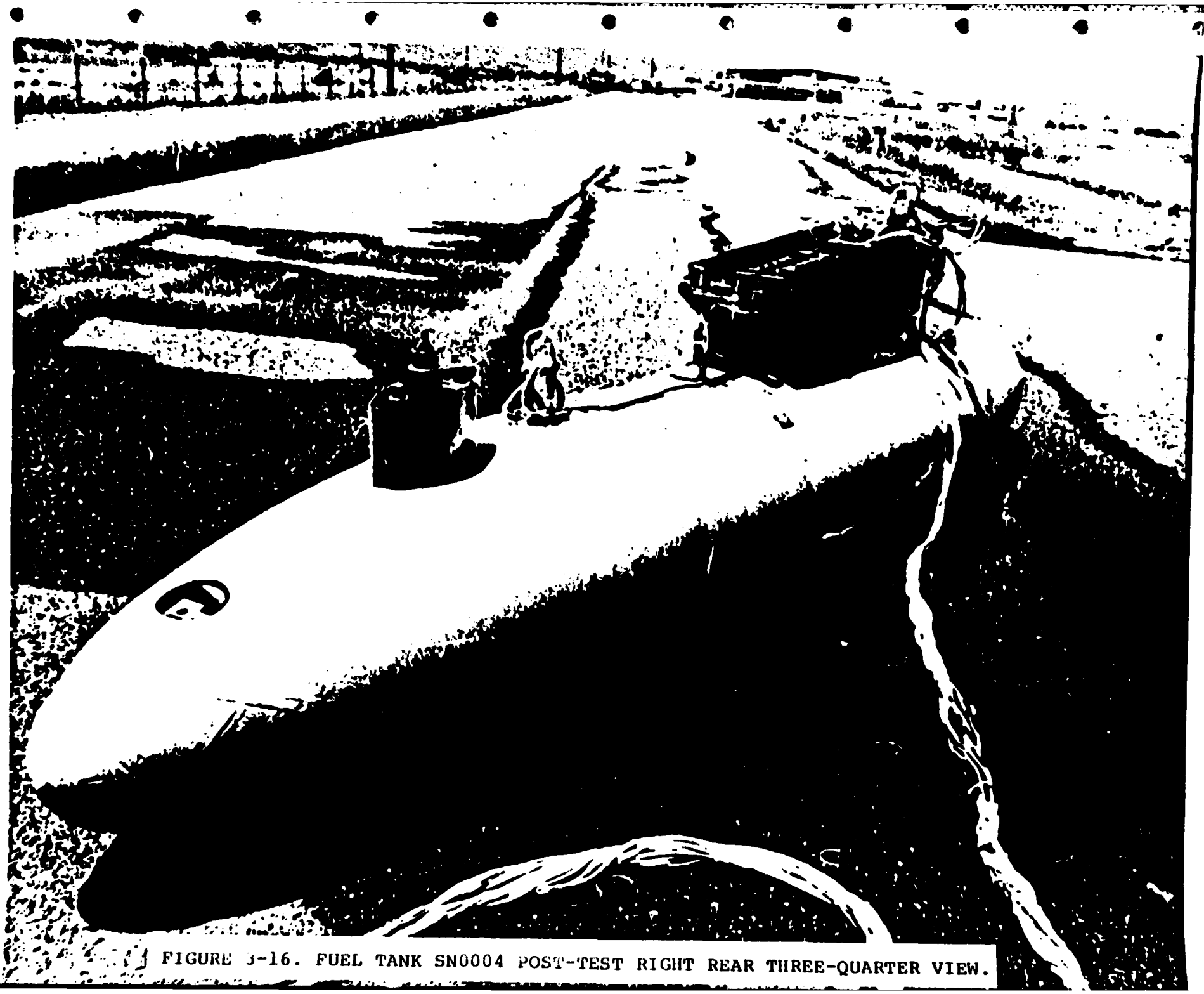


FIGURE 3-16. FUEL TANK SN0004 POST-TEST RIGHT REAR THREE-QUARTER VIEW.

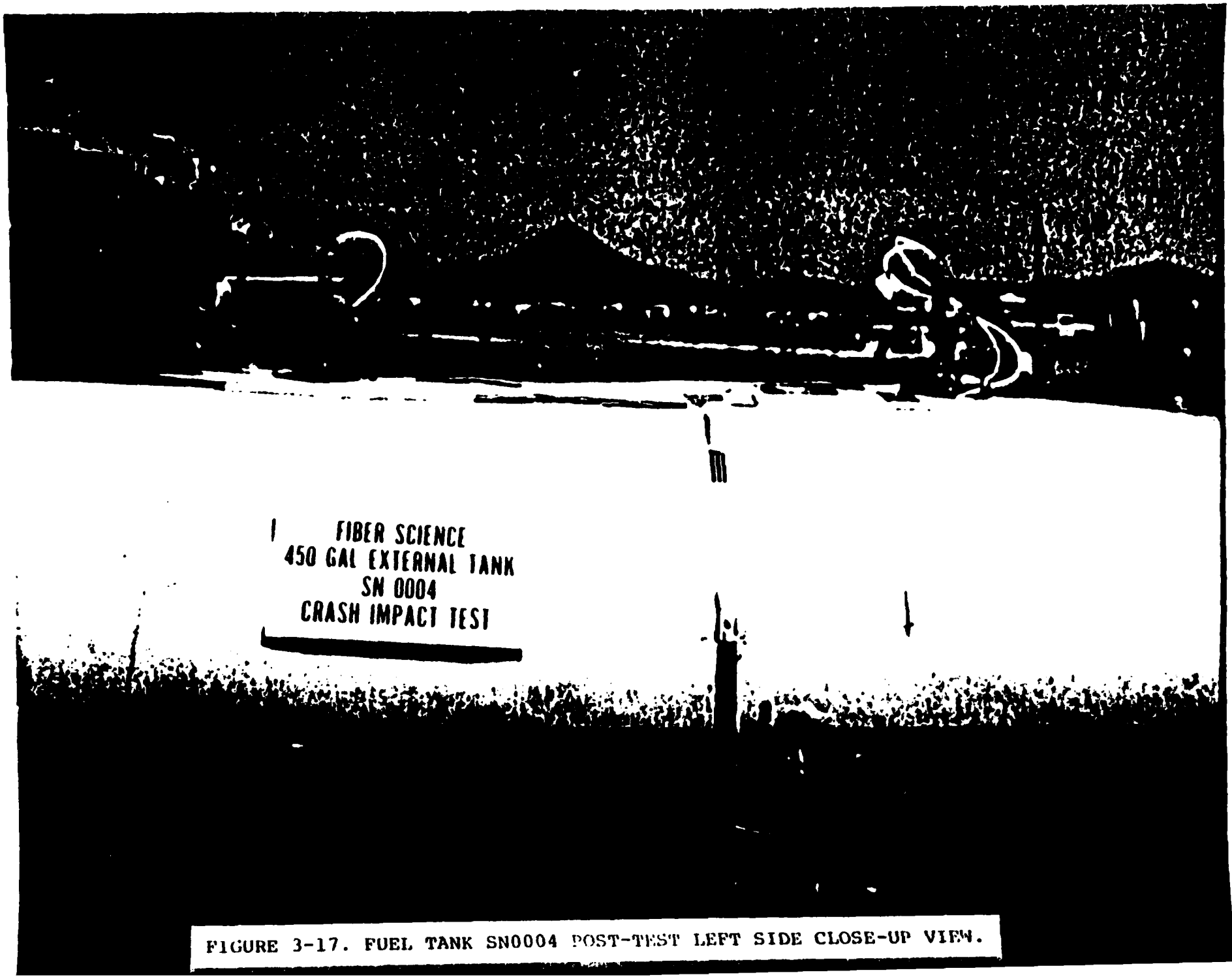


FIGURE 3-17. FUEL TANK SN0004 POST-TEST LEFT SIDE CLOSE-UP VIEW.

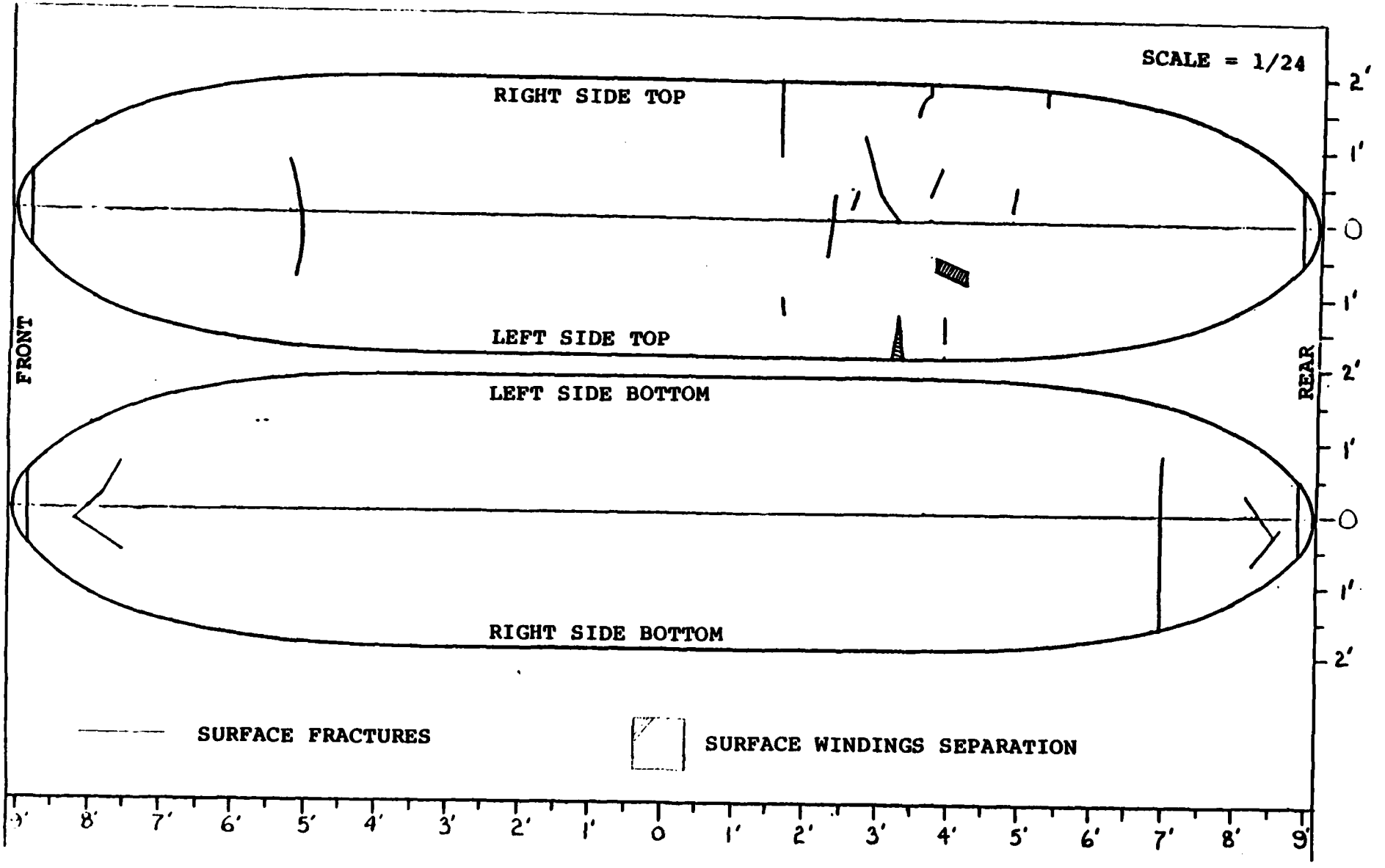


FIGURE 3-18. FUEL TANK SN0004 NON-RUPTURE SURFACE DAMAGE SKETCH.

FIGURE 3-19. FUEL TANK SN0004 POST-TEST FRONT BOTTOM CLOSE-UP VIEW.

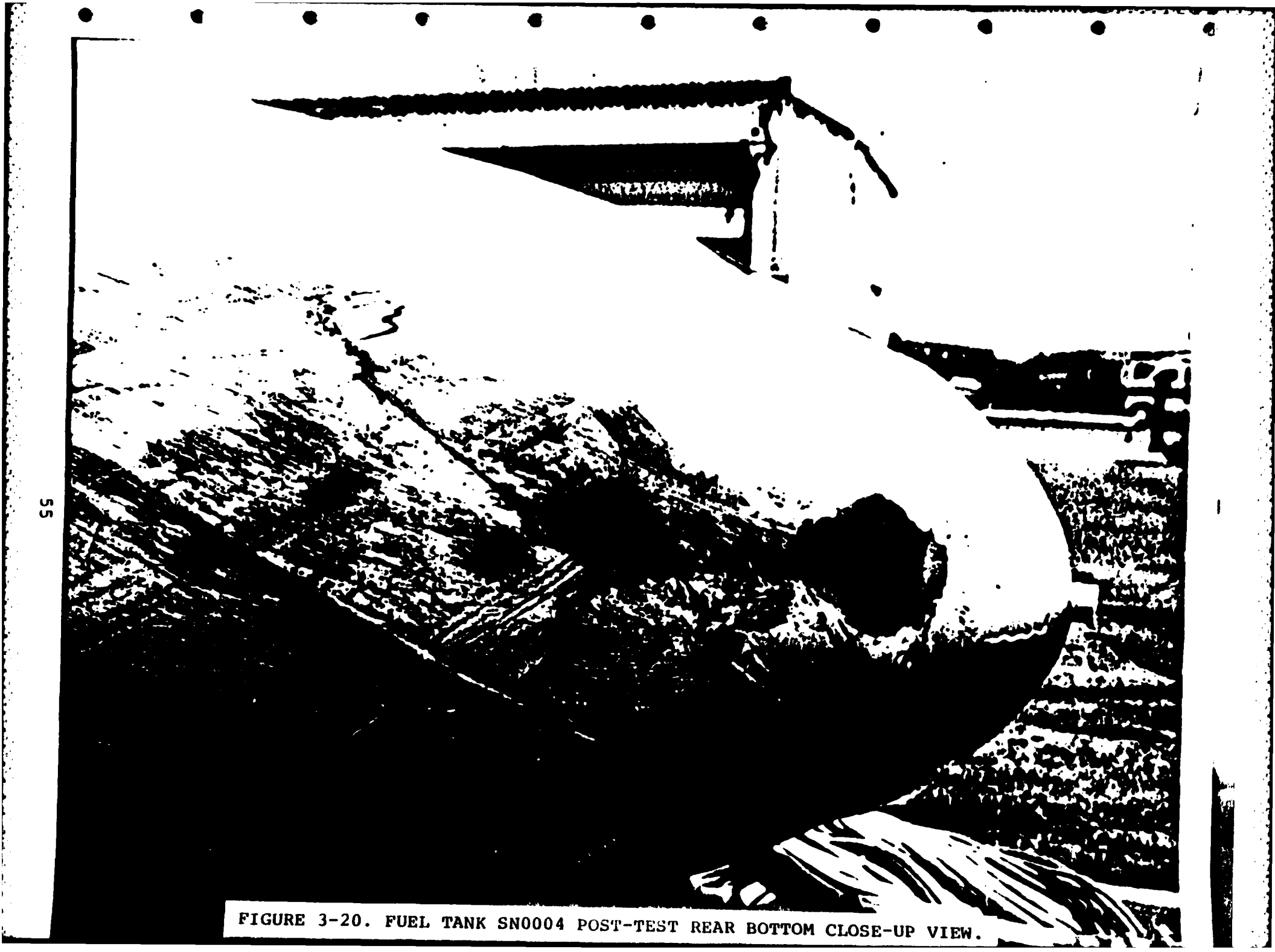


FIGURE 3-20. FUEL TANK SN0004 POST-TEST REAR BOTTOM CLOSE-UP VIEW.

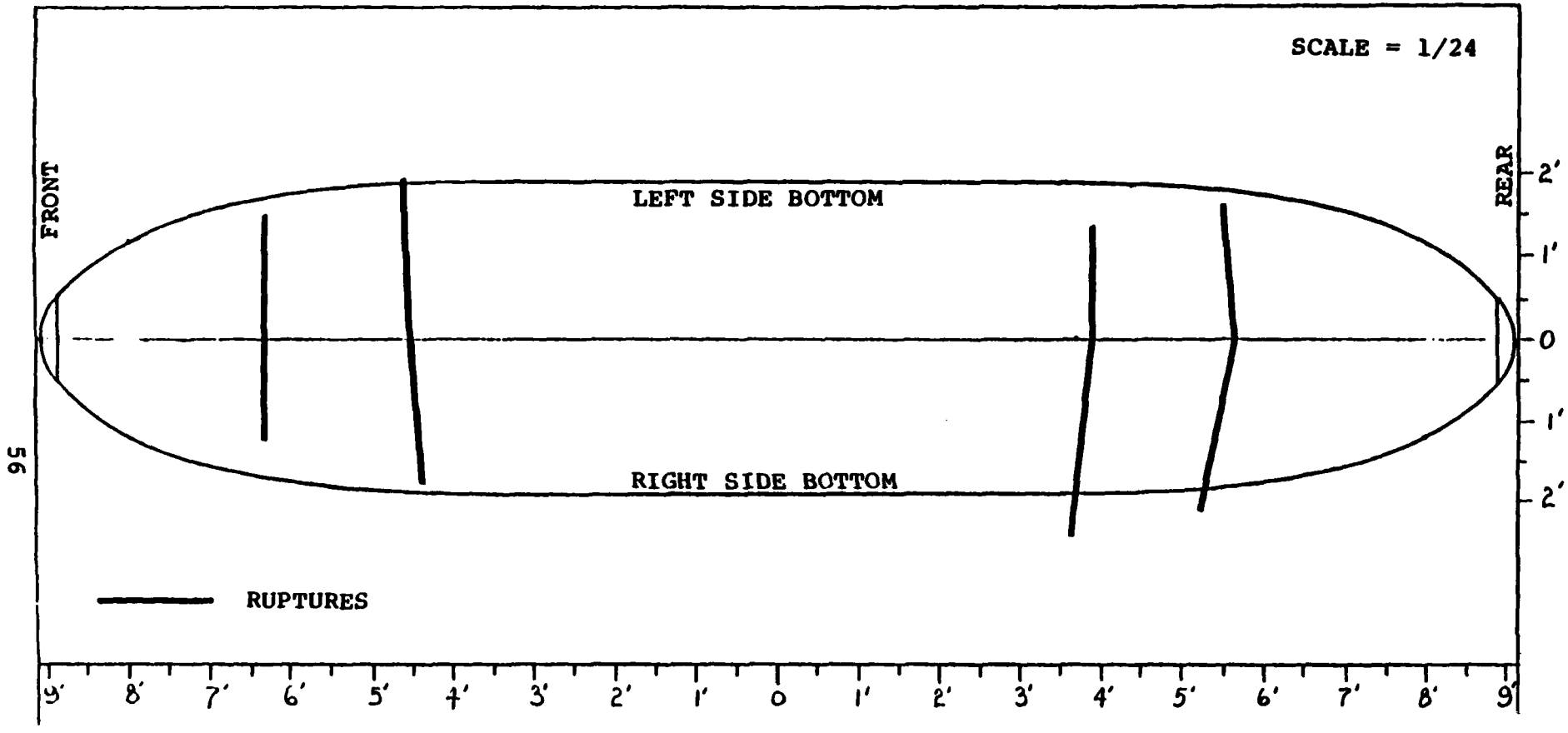
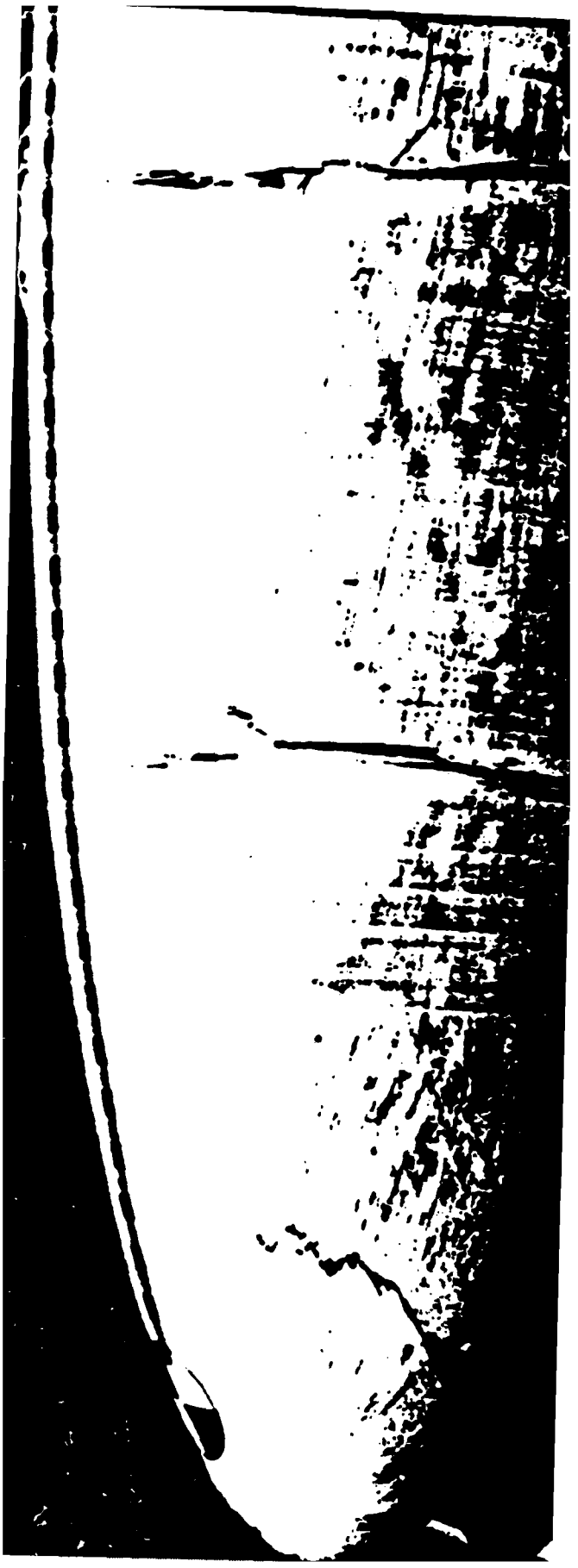


FIGURE 3-21. FUEL TANK SN0004 RUPTURE LOCATION SKETCH.



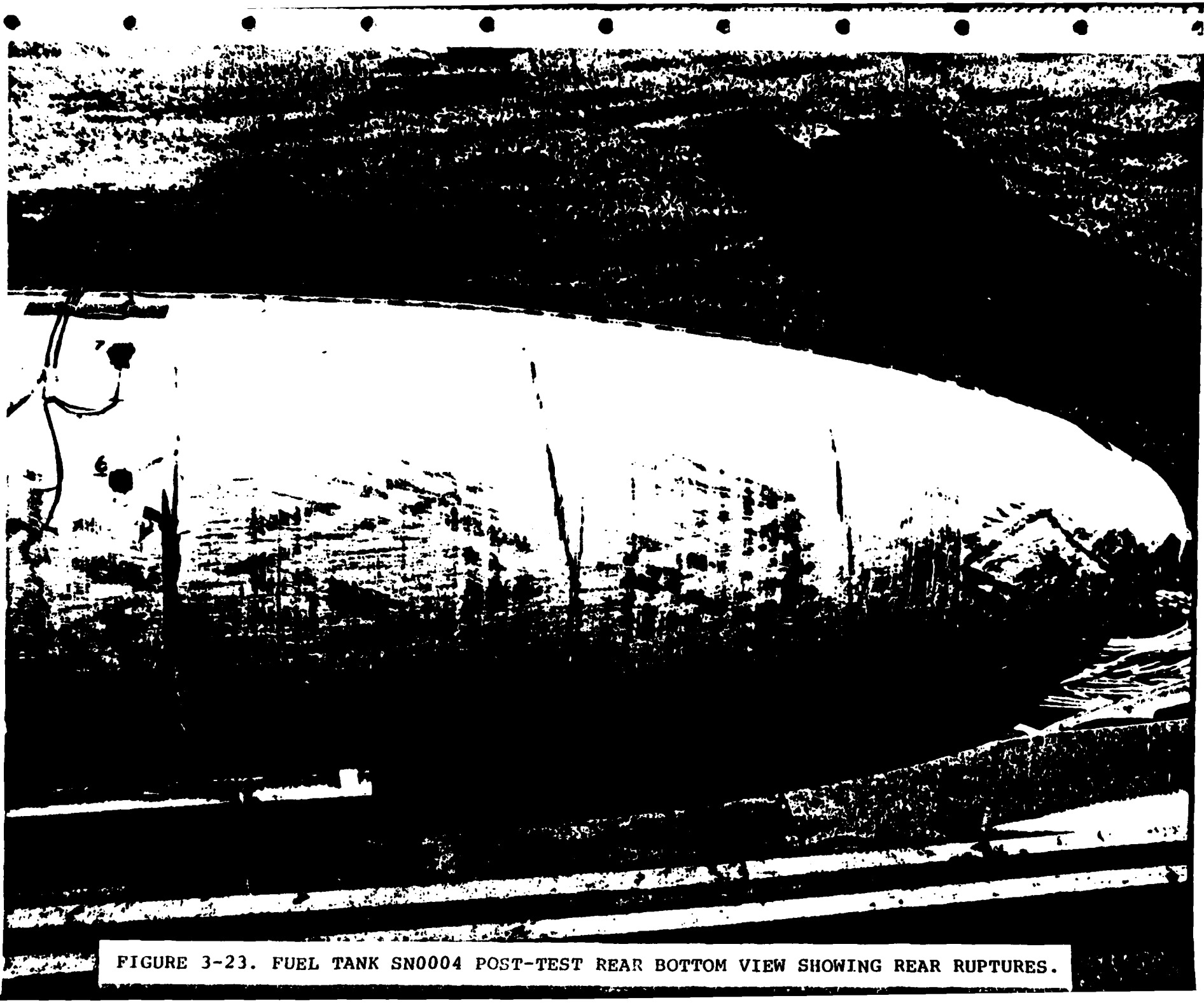


FIGURE 3-23. FUEL TANK SN0004 POST-TEST REAR BOTTOM VIEW SHOWING REAR RUPTURES.

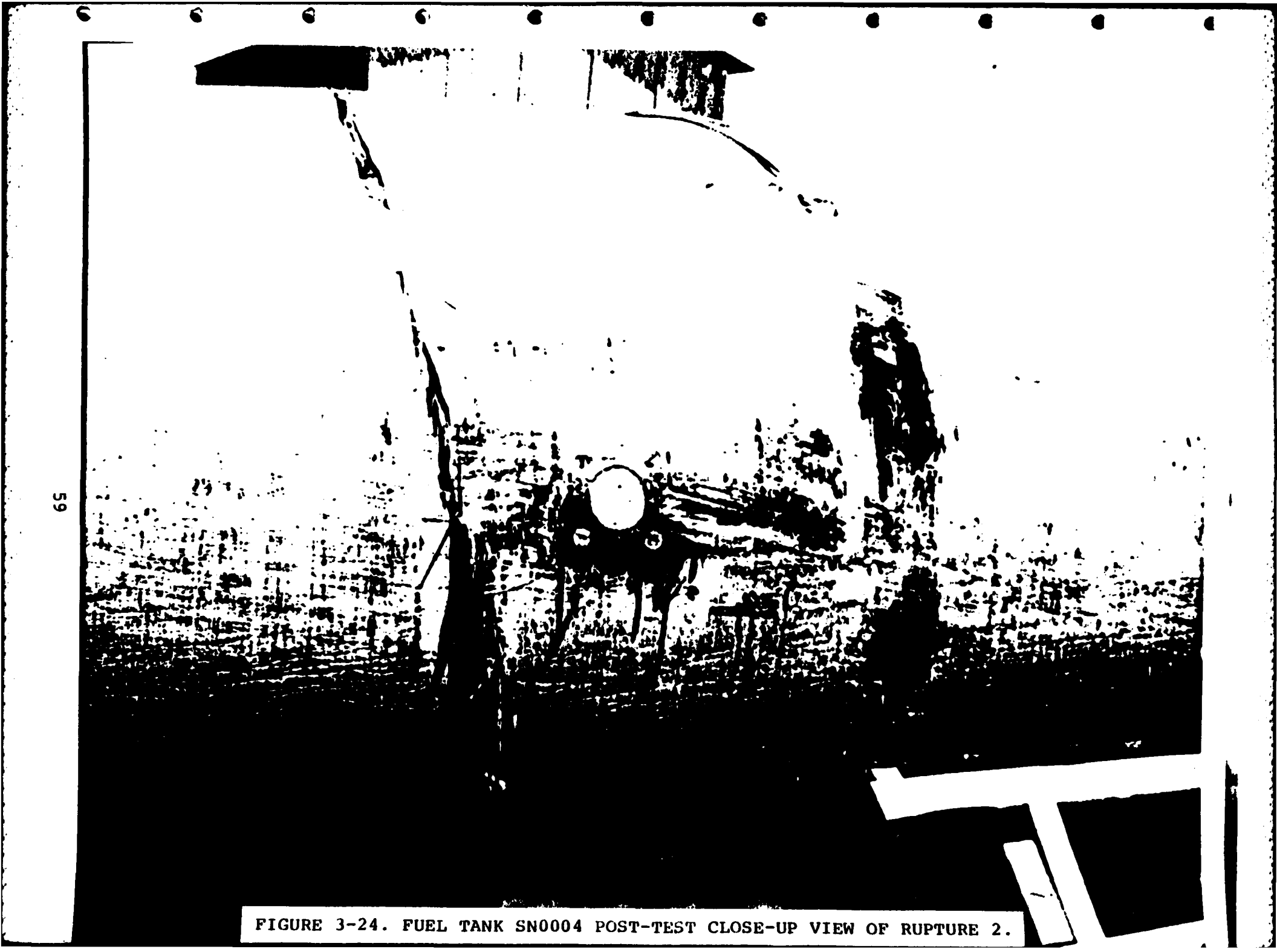


FIGURE 3-24. FUEL TANK SN0004 POST-TEST CLOSE-UP VIEW OF RUPTURE 2.

FIGURE 3-25. FUEL TANK SN0004 POST-TEST CLOSE-UP VIEW OF RUPTURE 3.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0004 (CONT)

Extent of Damage (Ruptures)

1. Irregular narrow fissure extending approximately one-half of tank circumference at this point. Top layer of glass/epoxy windings, graphite windings, and second layer of glass/epoxy windings exposed. Forward edge of fissure overlapped onto aft edge. Maximum post-test depth is 0.15". Graphite windings and helical glass/epoxy windings torn.

2. Same type fissure as rupture 1, but wider and more severe. Length is approximately one-half circumference. Maximum post-test depth is 0.40". Some distortion of circumferential glass/epoxy windings. Circumferential windings separated from graphite windings.

3. Fairly straight, wide fissure extending one-half circumference. Top layer of glass/epoxy, graphite, and second layer of glass/epoxy exposed. Forward edge of fissure overlaps rear edge. Failures in helical glass/epoxy and graphite windings. Maximum post-test depth is 0.50".

4. Primarily a narrow, irregular separation of circumferential winding fibers with some visible failure of graphite windings underneath, extending one-half circumference. Maximum post-test depth is 0.12".

CRASH IMPACT IMPRINT:

Besides previously described ruptures and fractures, entire bottom surface of tank is scuffed, primarily only to top layer of glass/epoxy windings, exposing either yellow or pink primer paint and the top layer of glass/epoxy windings. Black graphite windings exposed in several places, most notably near drain plug and near tail cap. No tearing of circumferential winding noted. Figure 3-26 is a scaled sketch of the impact imprint. Figure 3-27 shows an overall view of the bottom of the tank. Previous Figures 3-19, 3-20, 3-22, 3-23, 3-24, and 3-25 also document the impact area.

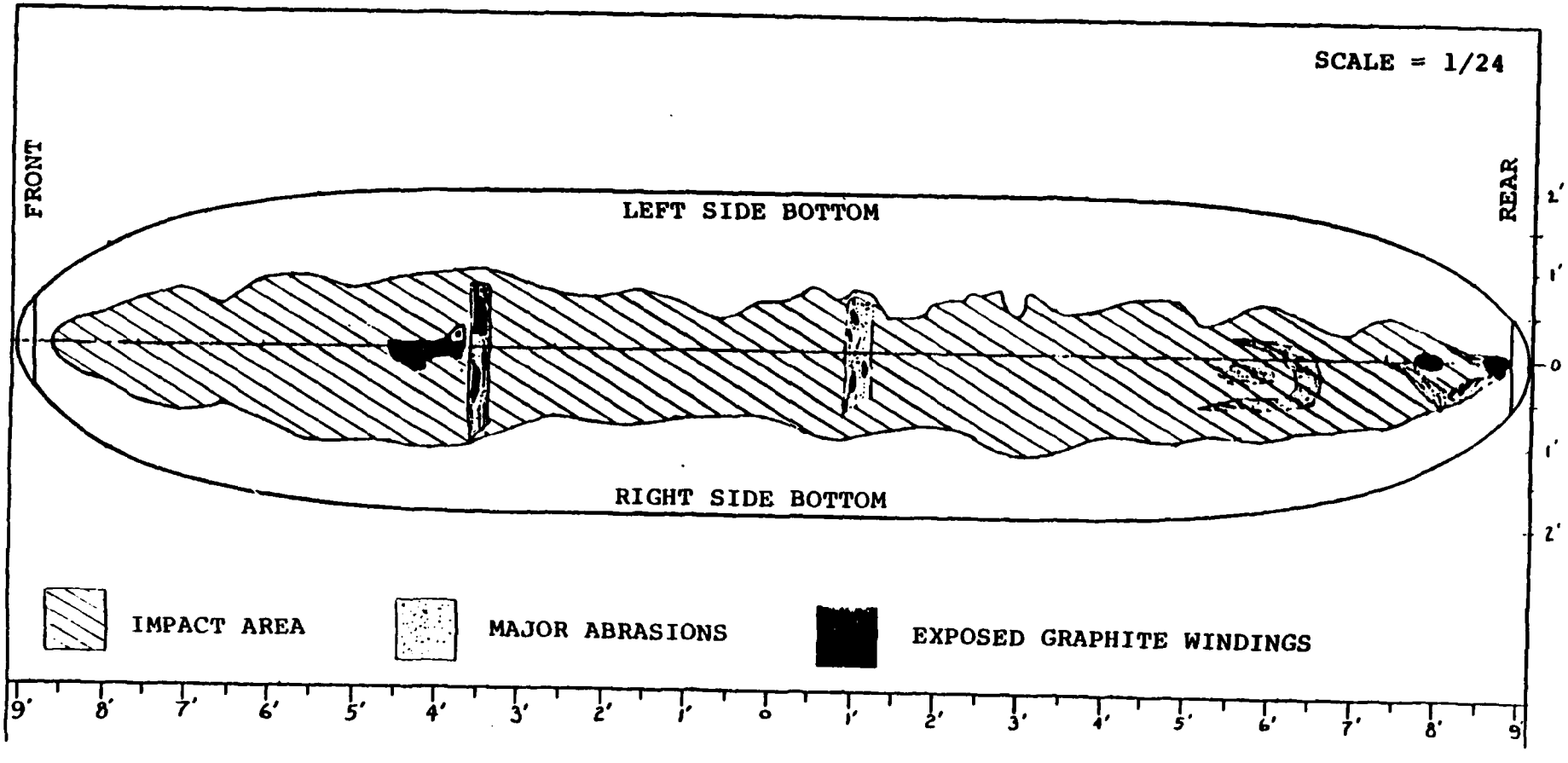


FIGURE 3-26. FUEL TANK SN0004 IMPACT IMPRINT SKETCH.

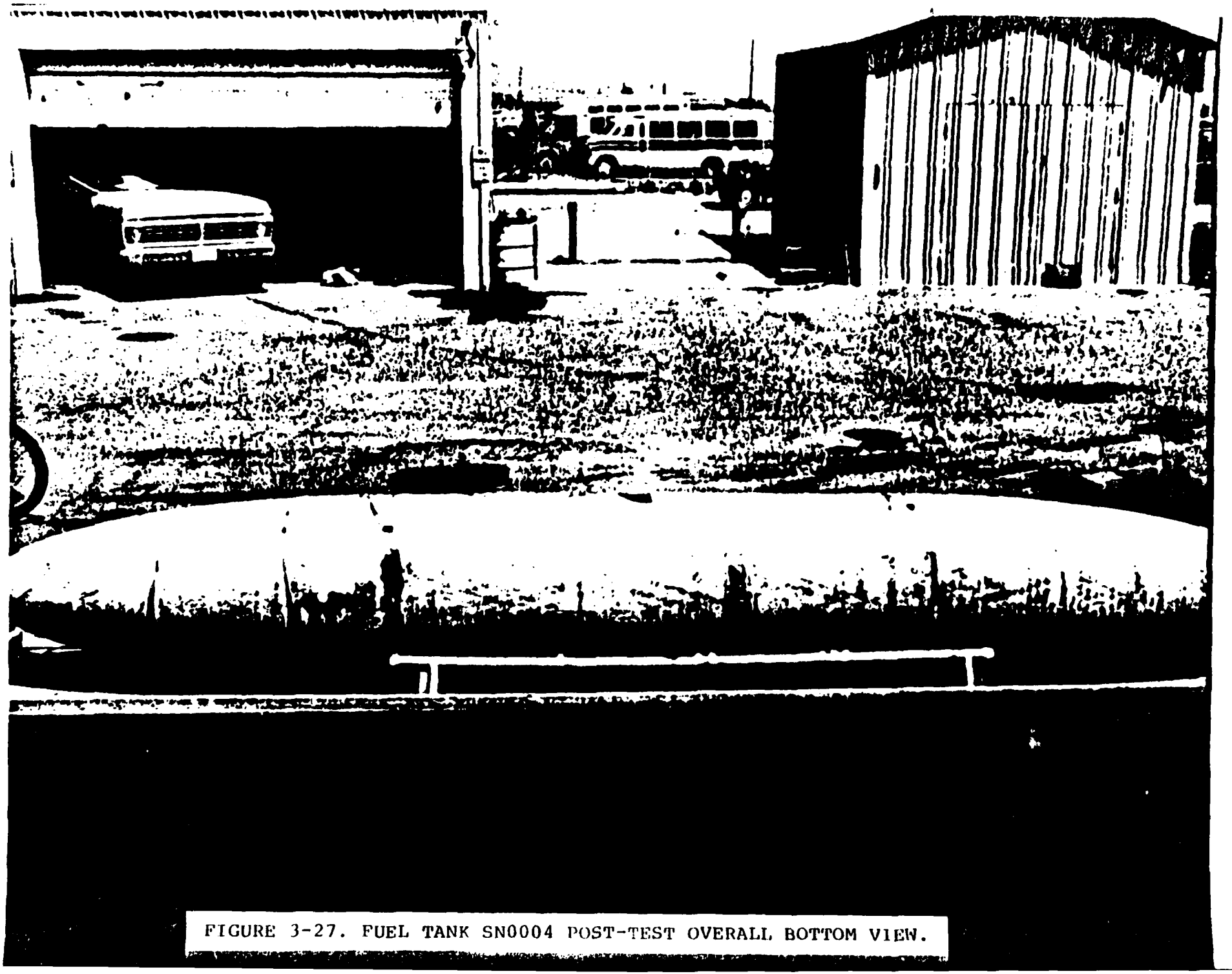


FIGURE 3-27. FUEL TANK SN0004 POST-TEST OVERALL BOTTOM VIEW.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0004 (CONT)

OTHER DAMAGE:

Final Distortion of Cross Sectional Shape

The cross sectional shape of the tank was measured after impact, while still containing water. At a point between the two rear access covers, the tank was 25" vertically and 32.5" across.

End Closures

Nose Cap - Hairline crack at bottom of cap near graphite windings.

Tail Cap - Hairline crack at top of cap near graphite windings.

Pylon Condition

No apparent crash induced damage. Gas vent line bent backwards.

Fuel & Air Fitting Condition

Black epoxy-like material around fuel fitting valve broken away. Float switch still functional. Figure 3-28 shows the fuel and air fittings. Small cracks in fairing.

Delaminations

Results of post-test Tap Test at Dynamic Science inconclusive. No real "dead" areas outside of visible impact and fracture areas. Entire tank sounded different than undamaged condition. Delaminations to be determined at a later date during cross-sectioning.

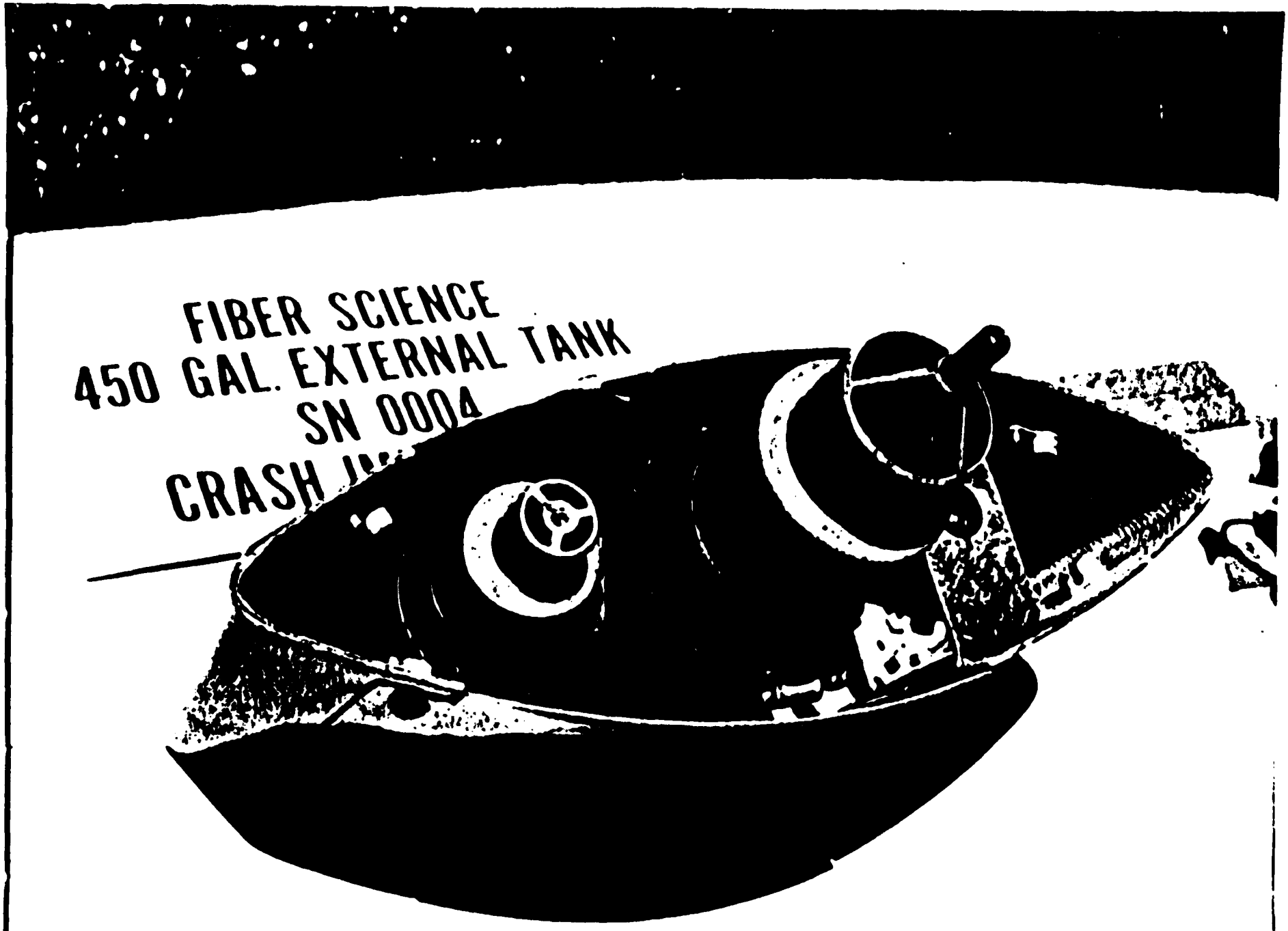


FIGURE 3-28. FUEL TANK SN0004 POST-TEST CLOSE-UP VIEW OF FUEL AND AIR FITTINGS.

(TO BE COMPLETED BY FIBER SCIENCE)

Ref. Para. 4.7.4: DELAMINATIONS

Results of Tap Test for Delaminations

"REFER TO TEST REPORT"

(Supply scaled sketch of size, location and approximate shape).

Ref. Para. 4.7.7 DISSECTION OF THE TANK

Approved By_____ Date_____

Condition of Frames

Condition of Probe

Condition of Float Switches

Condition of Fuel Line

(TO BE COMPLETED BY FIBER SCIENCE)

EVALUATION OF DATA

CAMERAS: "REFER TO TEST REPORT"

PRESSURE RECORDINGS:

STRAIN RECORDINGS:

3.3 TEST T4-1, TANK SERIAL NUMBER 0002

3.3.1 Test Conditions, SN0002

Following the failure of Tank SN0004 under the prescribed test conditions, it was decided to test Tank SN0002 (originally scheduled for a Forced Ejection Test) in a Crash Impact Test under slightly less severe conditions. Both the forward velocity and the drop height were reduced. In addition, because only 421 gallons of water had filled Tank SN0004 to the overflow condition in the previous test, the 2° nose-down filling condition for this tank design was waived for this test. Tank SN0002 was filled at 8° nose-down.

At the request of Fiber Science, three accelerometers were added to the instrumentation in order to measure vertical accelerations. In addition, the pressure sensor locations were changed for this test, at the request of Fiber Science. Because of a misinterpretation of instructions, all three sensors ended up measuring pressure at essentially the same location. Instrumentation for this test is recorded in Table 3-7.

The balance of test conditions for this test were the same as for the previous test. Table 3-8 documents photographic coverage. Table 3-9 presents a summary of test conditions. Figure 3-29 shows Tank SN0002 in its pre-test attitude. Data Sheet 1 documents pre-test approval.

3.3.2 Test Results, SN0002

When the ejection cartridges were fired, the tank and pylon released as desired, as shown in Figure 3-30, and fell to the asphalt. When the tank had come to rest leakage was such that the tank had obviously failed. The fluid was not collected. The tank was essentially drained within ten minutes after impact.

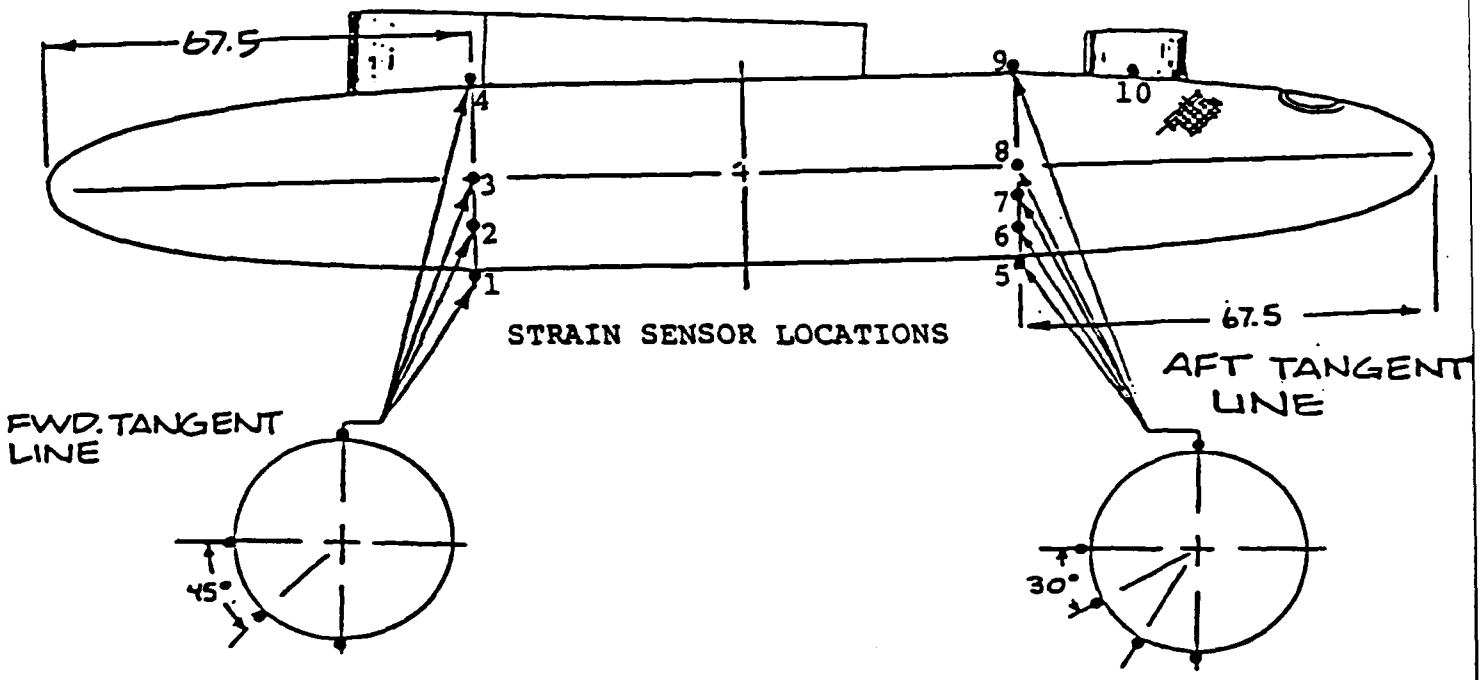
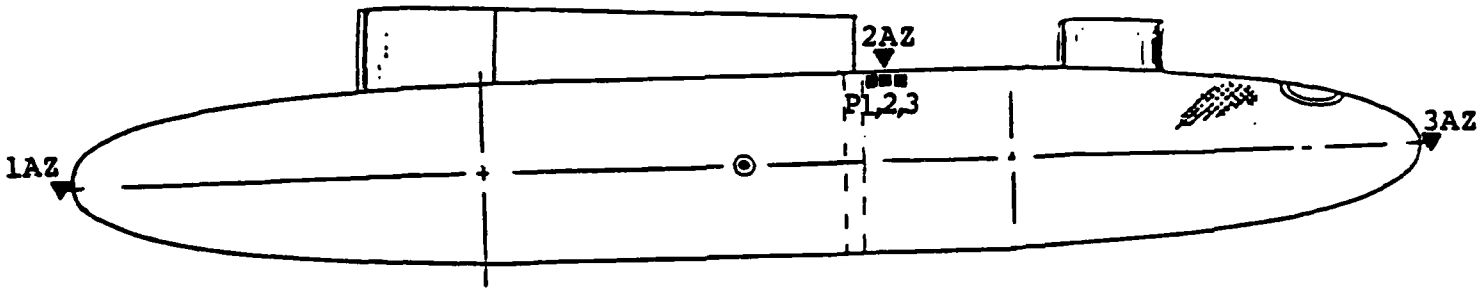


TABLE 3-7. CRASH IMPACT TEST INSTRUMENTATION - SN0002

STRAIN GAGE LOCATIONS		EXPECTED RANGES	
No.	Description of Location	Long. micro in./in.	Hoop micro in./in.
1	Fwd. Tangent, Bottom ℄	12.5 K	22.0 K
2	Fwd. Tangent, 45° Up Left Side from Bottom ℄	12.5 K	30.0 K
3	Fwd. Tangent, Left Side ℄	12.5 K	20.0 K
4	Fwd. Tangent, Top ℄	12.5 K	10.0 K
5	Aft Tangent, Bottom ℄	12.5 K	22.0 K
6	Aft Tangent, 30° Up Left Side from Bottom ℄	12.5 K	30.0 K
7	Aft Tangent, 60° Up Left Side from Bottom ℄	12.5 K	30.0 K
8	Aft Tangent, Left Side ℄	12.5 K	20.0 K
9	Aft Tangent, Top ℄	12.5 K	10.0 K
10	Between Fuel and Air Fittings, Top ℄	12.5 K	10.0 K



PRESSURE SENSOR AND
ACCELEROMETER LOCATIONS

TABLE 3-7. CRASH IMPACT TEST INSTRUMENTATION - SN0002 (CONTD).

PRESSURE SENSOR LOCATIONS		EXPECTED RANGES
No.	Description of Location	PSIA
P1	Through Aft Access Cover, Measures 2" Below Top $\mathbb{Q}_L$	650-700
P2	Through Aft Access Cover, Measures 2" Below Top $\mathbb{Q}_L$	650-700
P4	Through Aft Baffle Access Cover, Measures 2" Below Top $\mathbb{Q}_L$	650-700
	ACCELEROMETER LOCATIONS	EXPECTED RANGES
No.	Description of Location	G's (Z-axis)
1AZ	Nose Cap	250
2AZ	Aft Baffle Access Cover	250
3AZ	Tail Cap	250

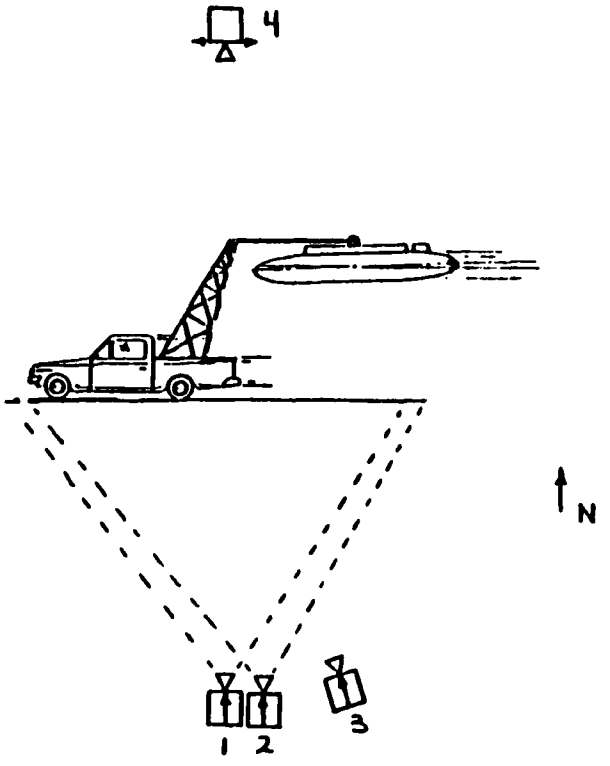
Test No: T4-1 Test Date: May 20, 1981

Test Type: Fuel Tank Crash Impact Test

Vehicle A: Crane With Fuel Tank

Vehicle B:

Comments: Qualification Test for Fiber Science
450 Gallon H-53 Helicopter External Tank



CAMERA	YES
STILLS	
SLIDES	x
MOVIE	x
POLAROID	
VIDEO	

CAMERA SYMBOLS

- PIT
- GROUND
- BARRIER
- OVERHEAD
- ON-BOARD
- PANNING

FRAME RATE

1. 1000 fr/sec
2. 200 fr/sec
3. Other 24 fr/sec
4. 400 fr/sec
5. 500 fr/sec

Loc. No.	Location	Field of View	Lens Size	Nom. Frm Rate	Timing (Hz)	Impact Dist-X	C.L. Dist-Y	CAM Hght-Z
1	South Side	Overall View of Crash Site*	15 mm	1	102			
2	South Side	Redundant for Camera 1	15 mm	1	102			
3	South Side	Close-up View of Tank During Crash Sequence*	43 mm	4	102			
4	North Side	Panning - Test and Results*	-	3	-			
		*Views included in test film.						

DSI FORM NO. TSO 125

TABLE 3-8. PHOTOGRAPHIC COVERAGE - SN0002.

TABLE 3-9. CRASH IMPACT TEST SUMMARY - TANK SN0002

Test Description: FSI 450 Gallon Tank Crash Impact Qualification Test

Tank Serial Number: 0002 Mfg. Date: April 1981

Test Number: T4-1

Number of Data Channels: 26

Number of Cameras: 4

Date: May 20, 1981 Time: 9:56 AM Temperature: 67°F

PRE-TEST DATA

Tank Empty Weight: 340.2 pounds
Target Horizontal Velocity: 32 ± 1.6 ft/sec
Target Vertical Velocity: 32 ± 1.6 ft/sec
Drop Height: 16'0"
Drop Attitude: 2° Nose-Up
Amount Water Introduced*: 462 Gallons

POST-TEST DATA

Impact Attitude: 1.25° Nose-Up
Actual Horizontal Velocity: 32.3 ft/sec
Actual Vertical Velocity**: 32.1 ft/sec
Number of Ruptures: 2
Leakage (Maximum Allowable = 1000 cc/min.): ≈40 gal./min.
Pass/Fail: Fail

*Based on pre- and post-filling weights of water wagon. Flow meter on water wagon registered 465 gallons.
**Based on initial height and/or free-fall times from electronic data and high-speed films.

FIGURE 3-29. PRE-TEST VIEW OF FUEL TANK SN0002 ATTACHED TO CRANE.

DATA SHEET 1. PRE-CRASH IMPACT EXAMINATION - TANK SN0002

Testing Activity: Dynamic Science, Inc.

Tank Serial No.: 0002

Test Date: May 20, 1981

Activity Test Engineer: Terry Bjork

FSI Test Engineer: Richard R. Lyman

Government Representative: Hugh Hilliard

EXAMINATION OF PRODUCT:

Visual Inspection: Approved - Only 2 Access Covers

Delaminations (Tap Test): Approved

MOUNTING:

Aircraft Simulated Attachment Deviations If Any: 2° nose-up instead of 2° nose-down. No aft pylon fairing used.

INSTRUMENTATION:

Check Proper Installation: Three accelerometers used. Three pressure transducers in aft frame access cap.

ARRANGEMENT:

Approved Test Arrangement:

Testing Activity Approval

Approved By Terry B. E Date 5-20-81

F.S.I. Test Engineer Approval

Approved By R. R. Lyman Date 20 MAY 81

Government Approval

Approved By Hugh Hilliard Date 20 May 81

Minimum of two signatures required.

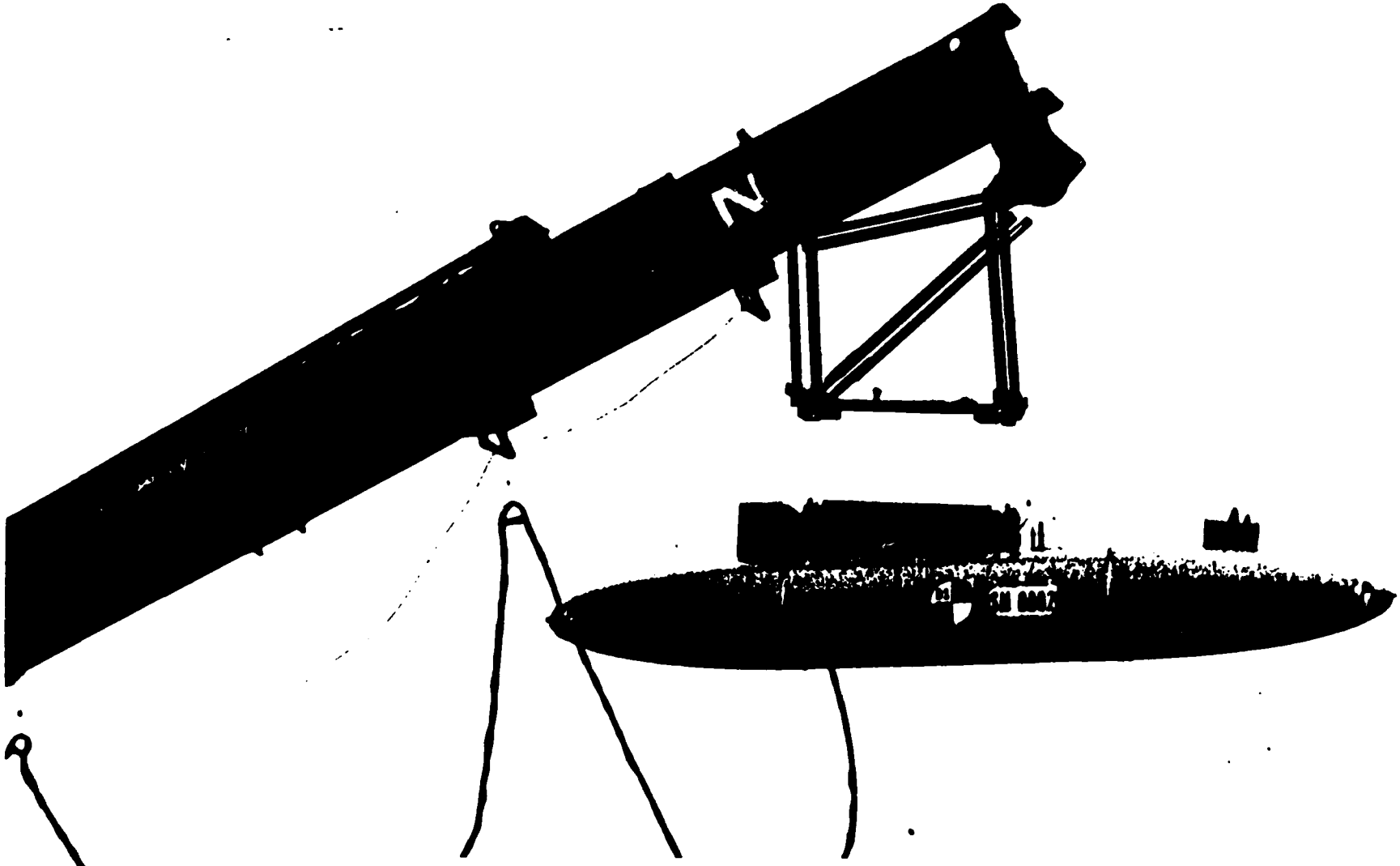


FIGURE 3-30. VIEW OF FUEL TANK SN0002 SHORTLY AFTER RELEASE.

Analysis of the high-speed films showed that the tank impacted the ground at approximately 1.25° nose-up. Upon impact, the tank flattened somewhat, and the tank ruptured, fore and aft. The tank rebounded fairly elastically off the asphalt, becoming completely airborne, as shown in Figure 3-31. While airborne, the tank rotated nose-up and began rolling to the right. The tank re-impacted the asphalt in approximately a 20° nose-up configuration. This second impact aggravated both ruptures and slightly buckled the tank over the aft rupture. The tank came down on its right side and skidded to a stop, leaking profusely from the forward rupture, as shown in Figure 3-32. The tank came to rest 47'5" from the initial impact point. The impact site for this test is shown in Figure 3-33.

3.3.2.1 Tank Damage and Electronic Data, SN0002

The damage to the tank is described in the text, damage sketches, and photographs of Data Sheet 2. The electronic data are presented as a series of computer generated plots in Appendix D.

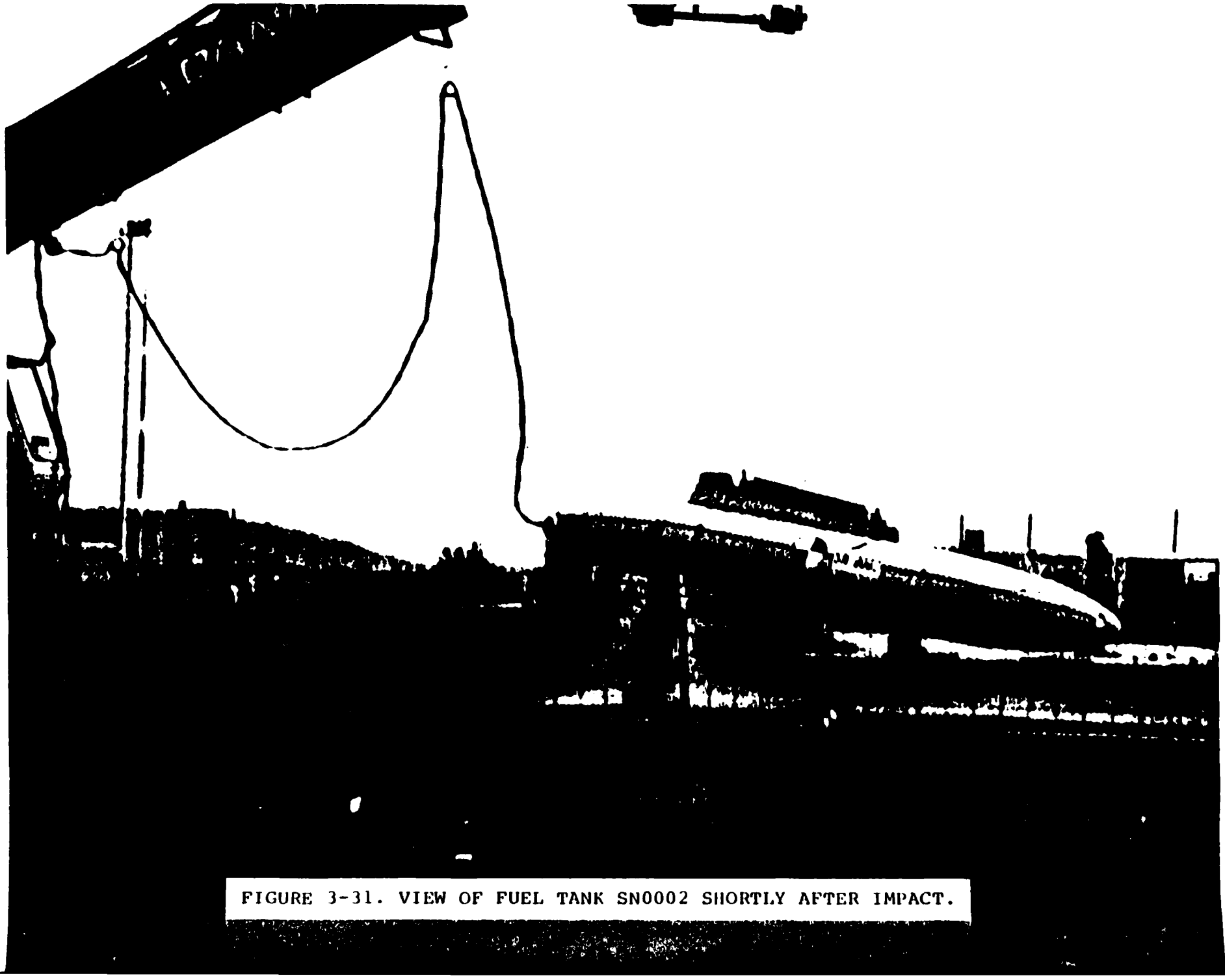


FIGURE 3-31. VIEW OF FUEL TANK SN0002 SHORTLY AFTER IMPACT.

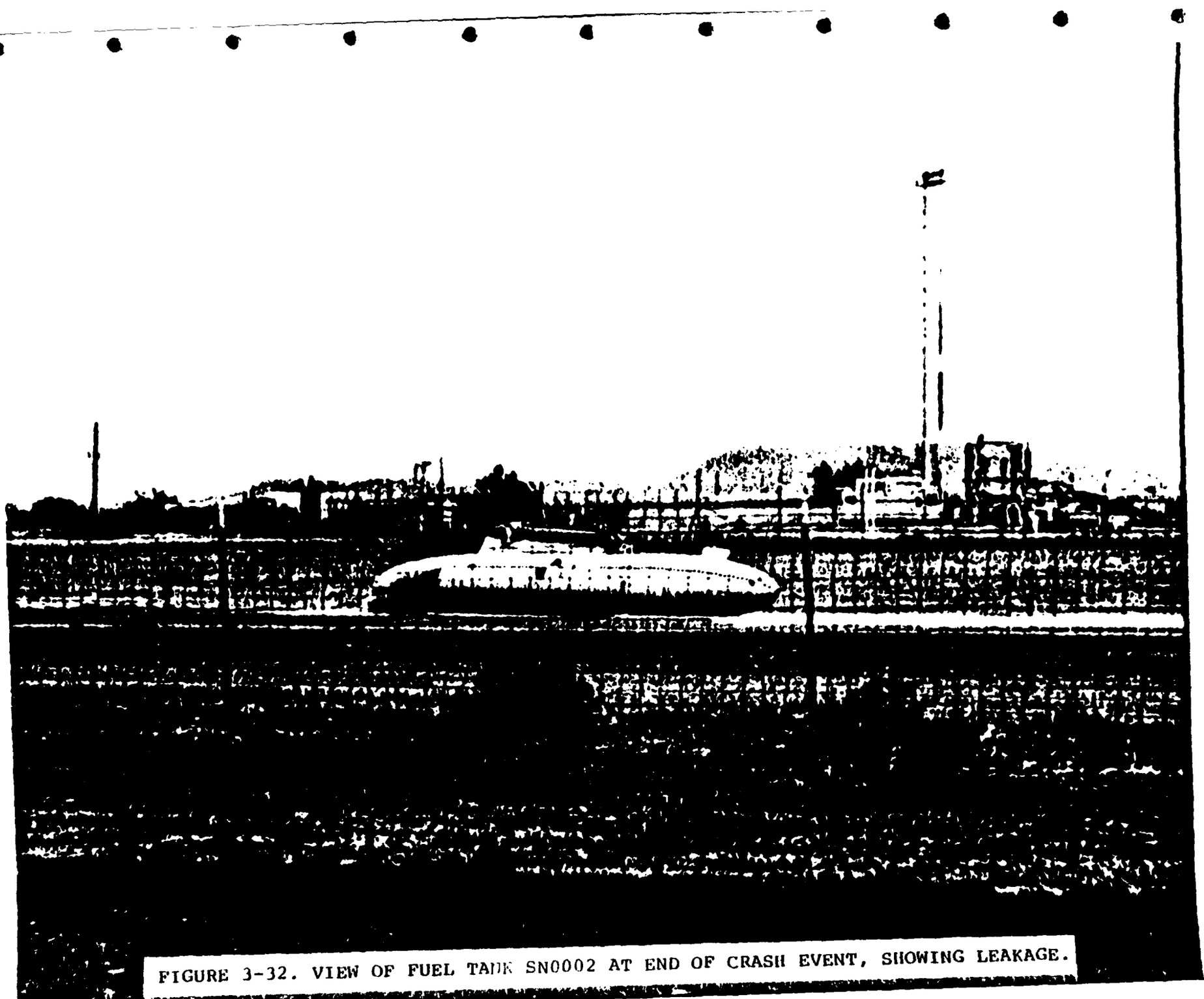


FIGURE 3-32. VIEW OF FUEL TANK SN0002 AT END OF CRASH EVENT, SHOWING LEAKAGE.

FIGURE 3-33. FUEL TANK SN0002 IMPACT SITE.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0002

GENERAL APPEARANCE:

General overall appearance is poor. There are two large ruptures, one fore and one aft. There are also three partial fractures on the bottom of the tank, one forward of the fore rupture, one just forward of the rear rupture, and one aft of the rear rupture near the tail. There are deep scuffs on the bottom and right side of the tank. Additionally, surface stress fractures are evident on the top and sides of the tank. Figure 3-34 is a sketch of non-rupture surface damage. Figure 3-35 shows a general view of damage to the bottom of the tank.

LEAKAGE:

Leakage was not collected. Tank nearly completely drained out the two ruptures within ten minutes of impact. Leakage at forward rupture was more severe than rear.

RUPTURES:

Two leakage locations were noted. Figure 3-36 is a scaled sketch of the rupture locations.

Locations

1. Approximately 5.0' forward of tank center point on bottom.
2. Approximately 5.0' aft of tank center point on bottom.

Extent of Damage

1. Jagged, tearing fissure extending about one-half circumference. Nearly all failure in helical windings, with some circumferential failure at bottom of tank. All layers down to thermoplastic liner exposed; more severe on tank left side. Pieces of honeycomb protruding through rupture. Figure 3-37 shows a close-up view of this rupture.

2. Very straight, narrow fissue extending approximately one-half circumference on bottom of tank. Nearly all failure in helical windings. All layers exposed down to thermoplastic liner. More of a clean splitting failure than the tearing of rupture 1. Figure 3-38 shows a close-up view of this rupture.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0003 (CONT)

Pylon Condition

No apparent impact-induced damage. Gas vent line bent forward.

Fuel and Air Fitting Condition

Not used. Machined aluminum plugs in place.

Delaminations

Tap Test for Delaminations deleted per Fiber Science instructions.

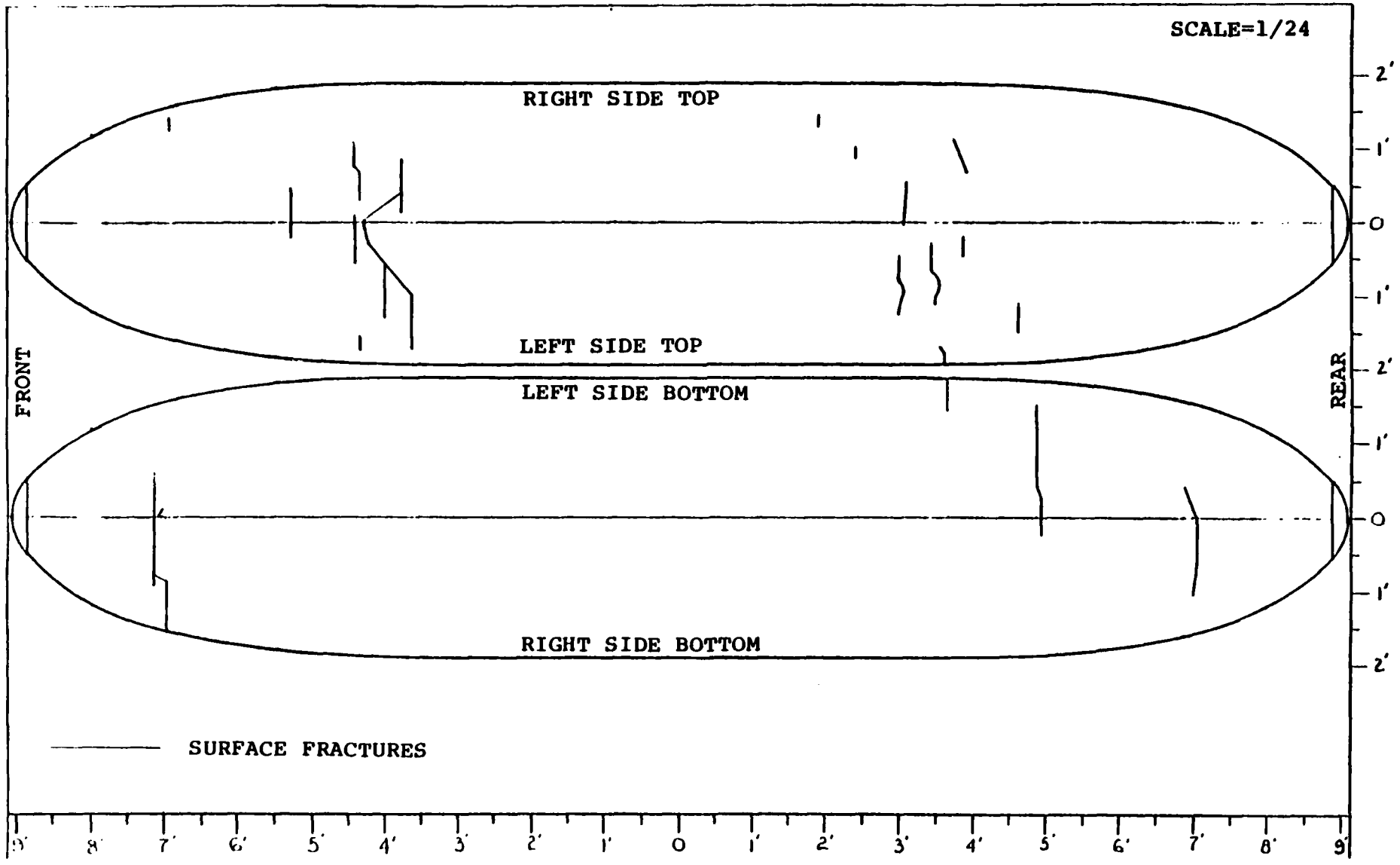


FIGURE 3-34. FUEL TANK SN0002 NON-RUPTURE SURFACE DAMAGE SKETCH.

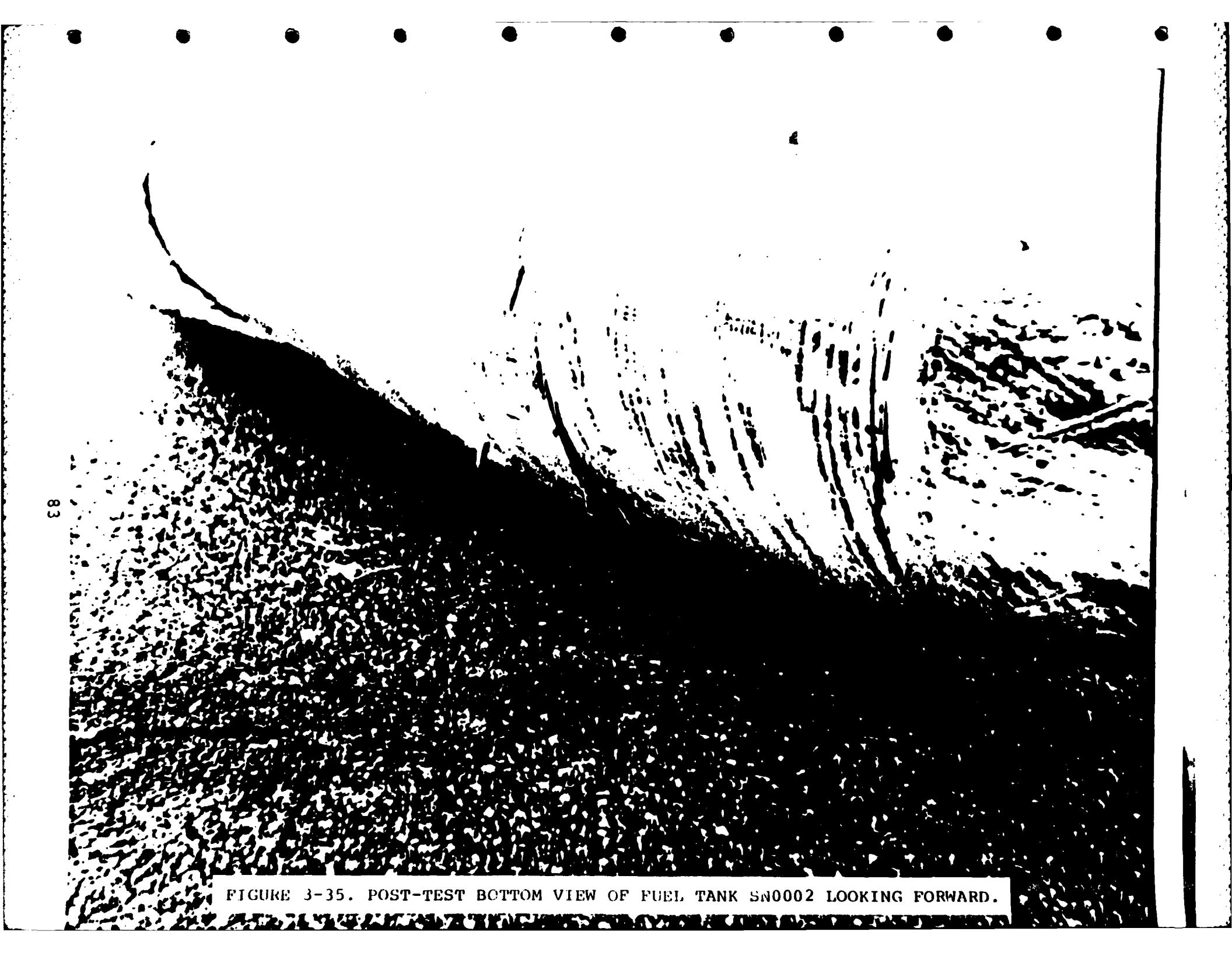


FIGURE 3-35. POST-TEST BOTTOM VIEW OF FUEL TANK SN0002 LOOKING FORWARD.

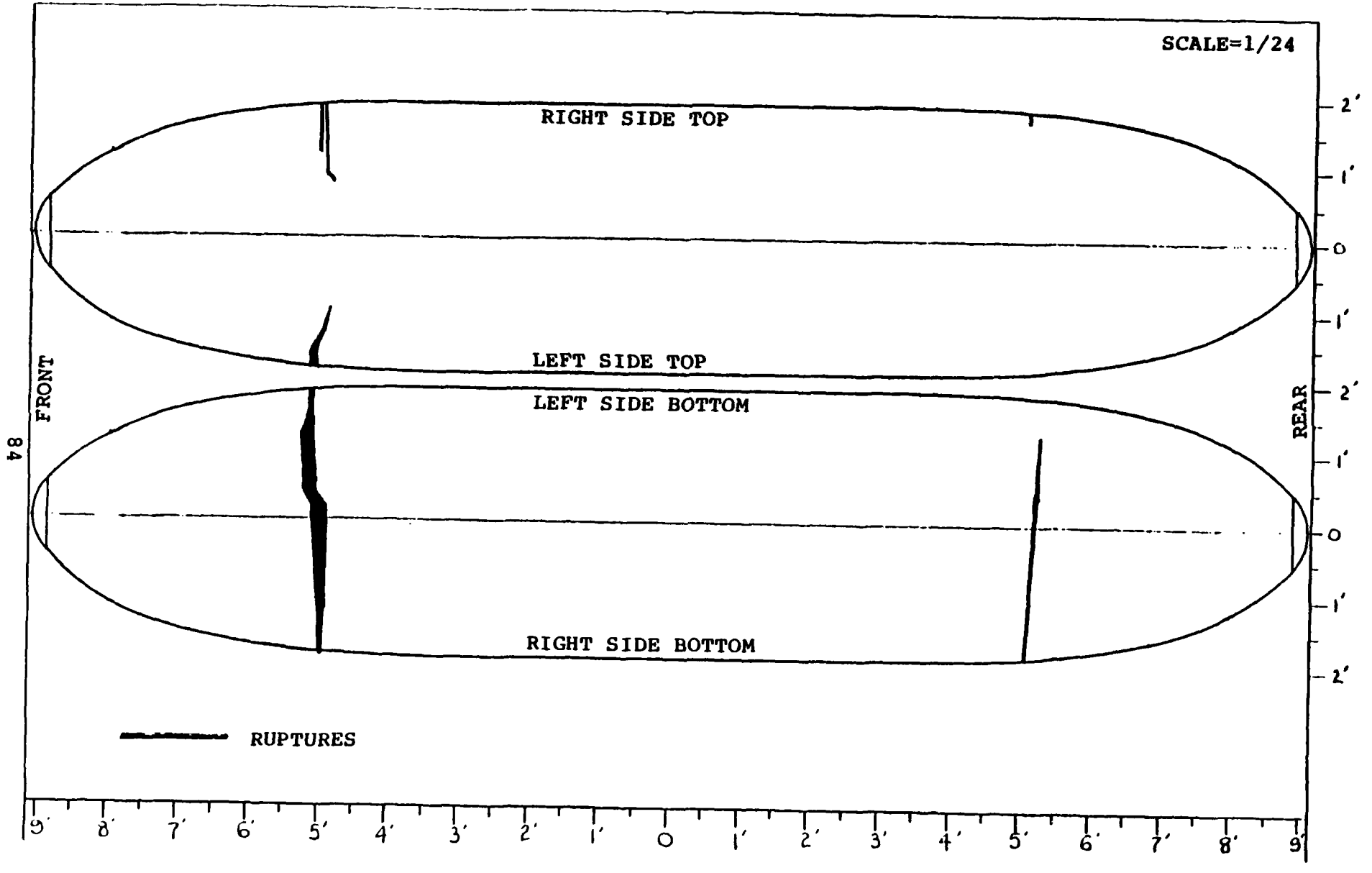


FIGURE 3-36. FUEL TANK SN0002 RUPTURE LOCATION SKETCH.

FIGURE 3-37. POST-TEST FRONT BOTTOM VIEW OF TANK SN0002, SHOWING FORWARD RUPTURE.

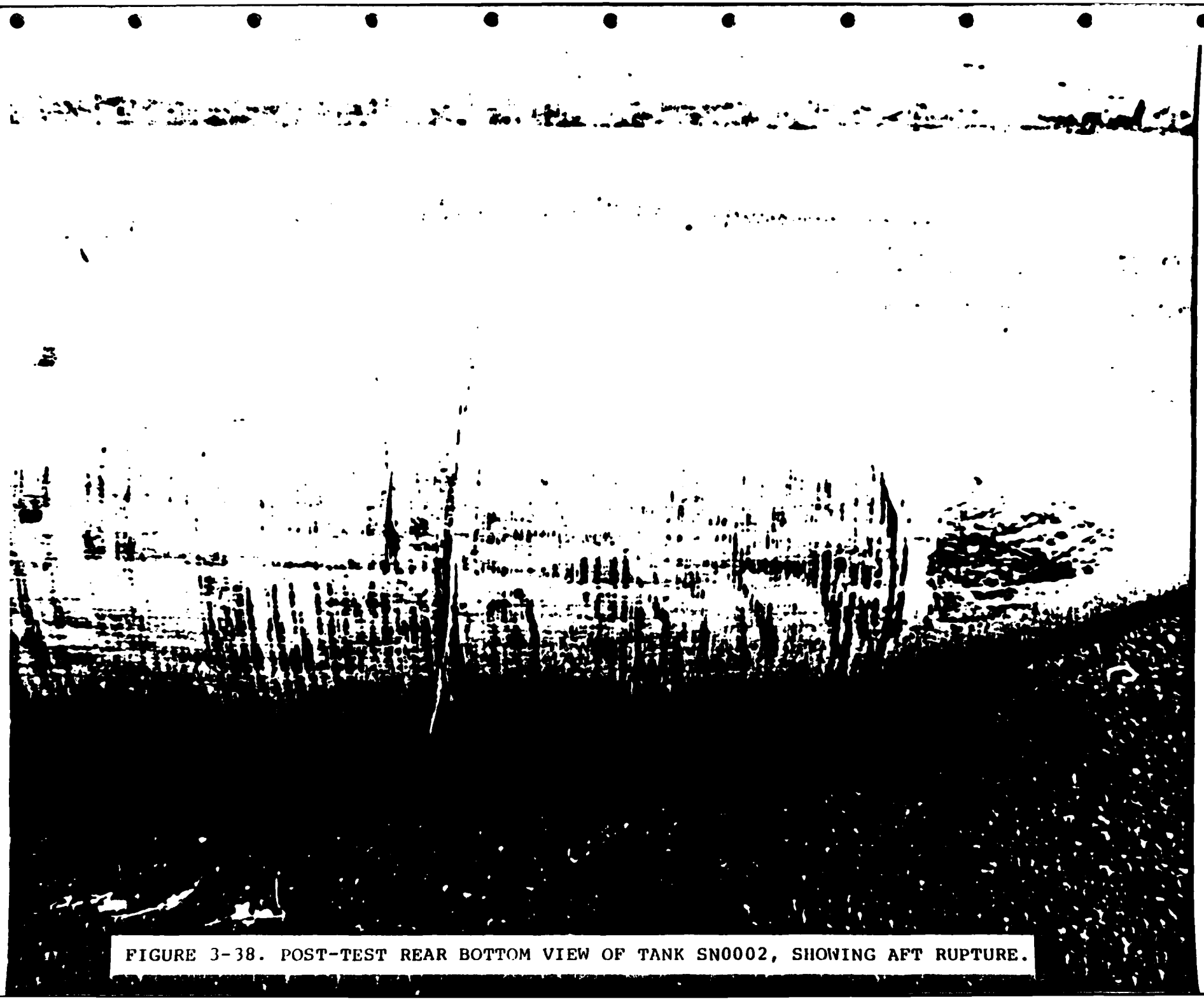


FIGURE 3-38. POST-TEST REAR BOTTOM VIEW OF TANK SN0002, SHOWING AFT RUPTURE.

DATA SHEET 2. POST-CRASH IMPACT EXAMINATION - TANK SN0002 (CONT)

CRASH IMPACT IMPRINT:

Aside from ruptures and fractures, most other damage consists of scuffing, exposing primarily yellow primer paint and outside layer of circumferential glass/epoxy windings. Graphite windings scuffed at front and rear. Graphite windings exposed on right side bottom aft of drain plug, also on right side bottom even with rear of pylon. Impact imprint consists of tank bottom and right side. Figure 3-39 is a scaled sketch of the impact imprint area. Figure 3-40 shows an overall view of the tank bottom impact area.

OTHER DAMAGE:

Final Distortion of Cross Sectional Shape

The tank was measured when empty.

At a point 67.5" from the tail
Height = 28.9", Width = 29.7"

At a point 67.5" from the nose
Height = 28.8", Width = 30.3"

End Closures

Nose Cap - No damage.

Tail Cap - No damage.

Pylon Condition

Bottom of pylon bent upward from front mounts to rear mounts. Gas vent line bent backwards.

Fuel & Air Fitting Condition

No damage except hairline cracks in the fairing. Figure 3-41 shows the fuel and air fittings. Figure 3-42 shows the aft filler access.

Delaminations

Results of post-test Tap Test at Dynamic Science inconclusive. No real "dead" areas outside of visible impact and fracture areas. Entire tank sounded different than undamaged condition. Delaminations to be determined at a later date during cross-sectioning.

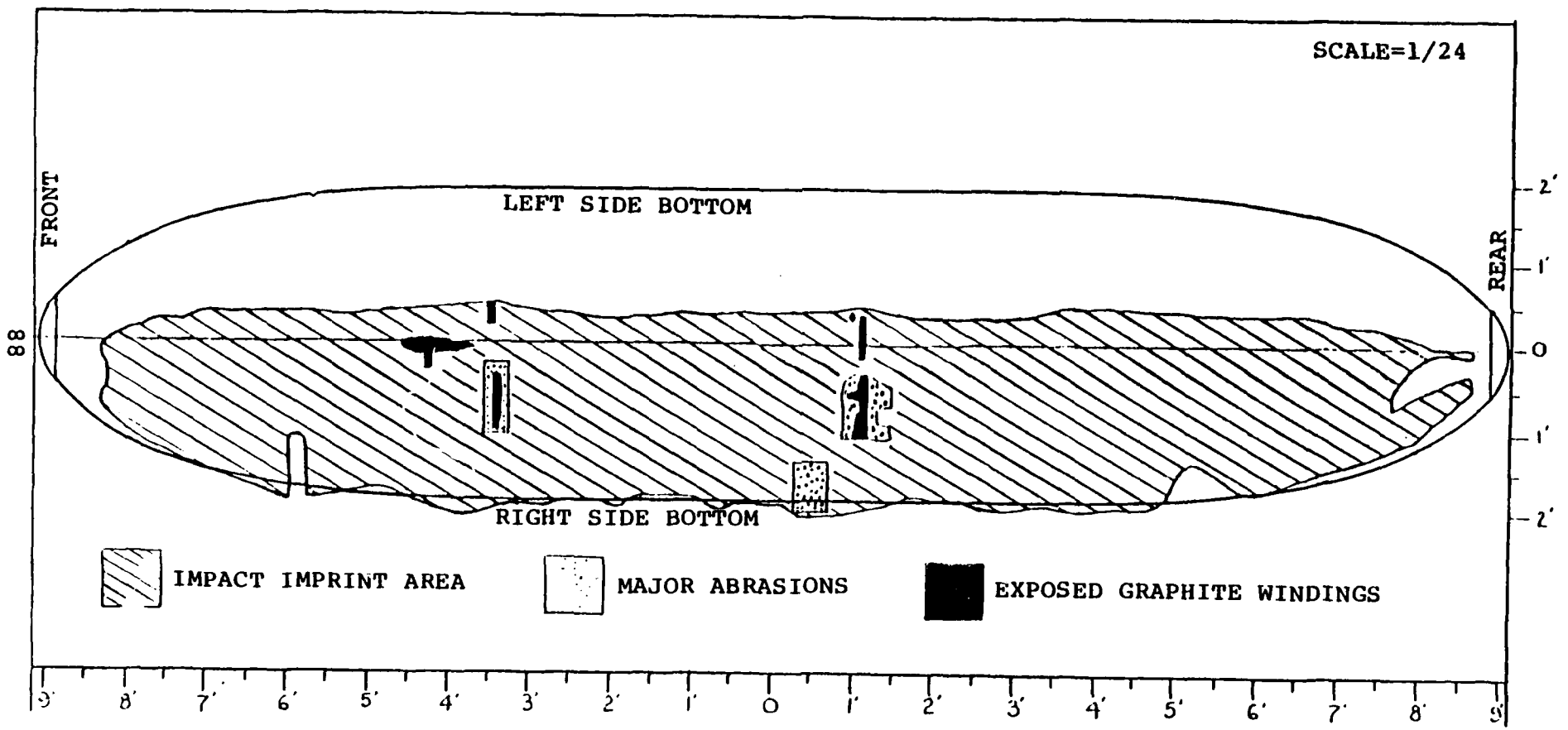
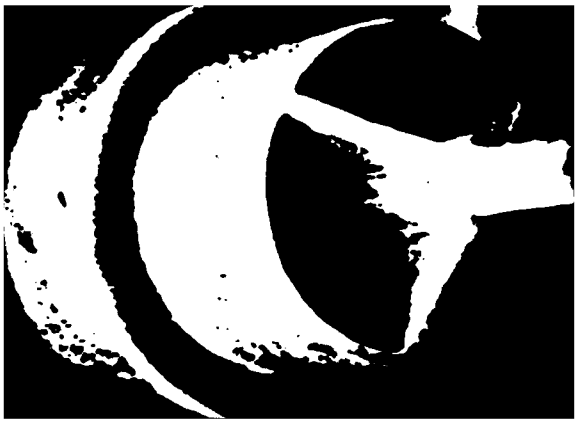


FIGURE 3-39. FUEL TANK SN0002 IMPACT IMPRINT SKETCH.

FIGURE 3-40. POST-TEST BOTTOM OVERALL VIEW OF TANK SN0002 IMPACT AREA.



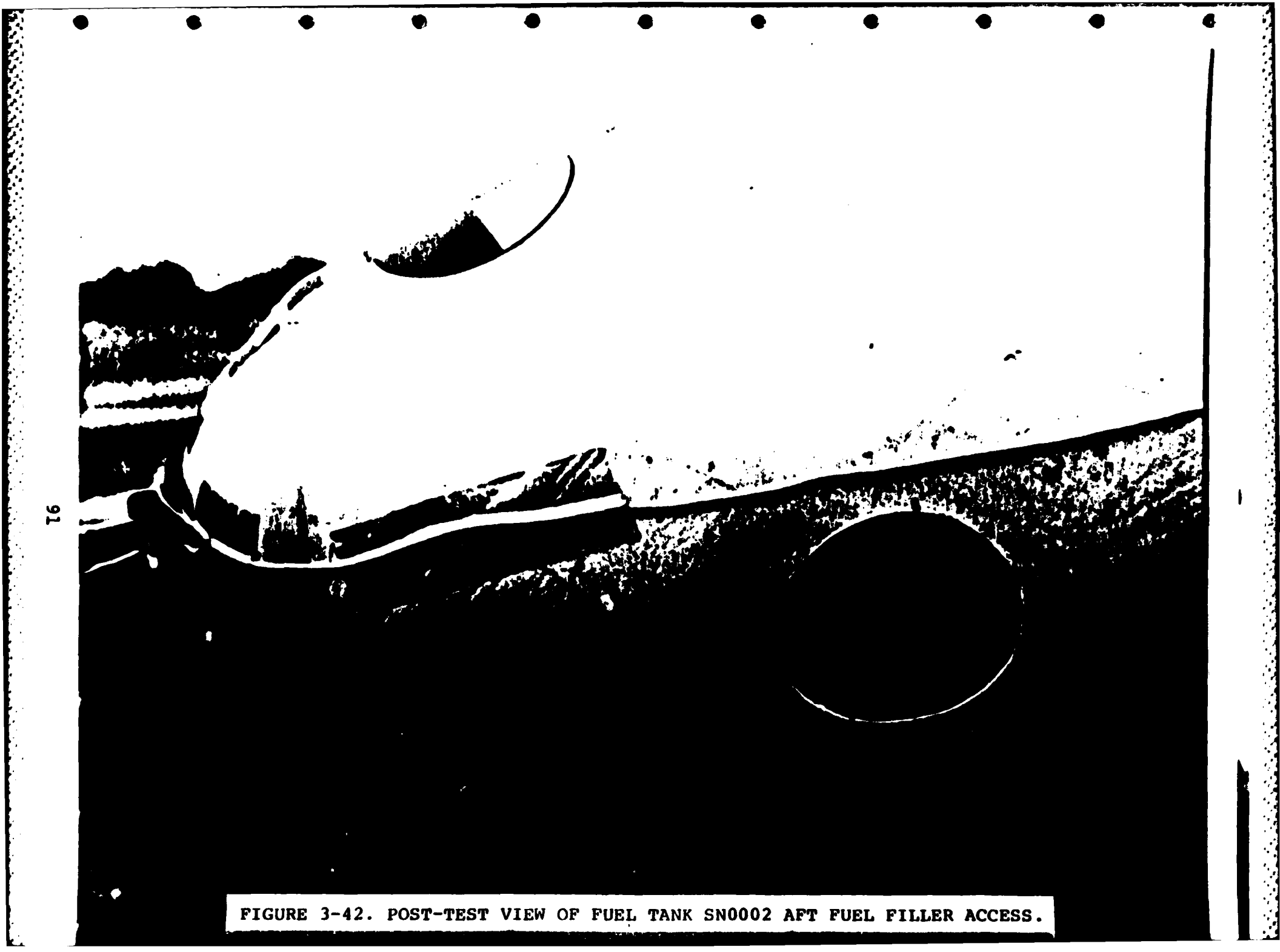


FIGURE 3-42. POST-TEST VIEW OF FUEL TANK SN0002 AFT FUEL FILLER ACCESS.

(TO BE COMPLETED BY FIBER SCIENCE)

Ref. Para. 4.7.4: DELAMINATIONS

Results of Tap Test for Delaminations

"REFER TO TEST REPORT"

(Supply scaled sketch of size, location and approximate shape).

Ref. Para. 4.7.7 DISSECTION OF THE TANK

Approved By_____ Date_____

Condition of Frames

Condition of Probe

Condition of Float Switches

Condition of Fuel Line

(TO BE COMPLETED BY FIBER SCIENCE)

EVALUATION OF DATA

CAMERAS: "REFER TO TEST REPORT"

PRESSURE RECORDINGS:

STRAIN RECORDINGS:

APPENDIX A

Interpretation of Test Data

INTEPRETATION OF TEST DATA

A. Pressure Data - Throughout this test series, it was noted that the pressure sensors were recording sizable negative pressures. It is unlikely that this phenomena actually exists as deformation of the tank upon impact results in decreased volume, which in turn should result in increased pressure. It is believed that the source of this condition is the low frequency response of the transducer/tank data acquisition sub-system. It is possible that the natural frequency of the transducers was altered by the additional mass of the liquid introduced into the tank. This additional mass then reduced the natural frequency of the sub-system and may have changed the damping coefficient upon which calibration values are established. Because of this occurrence, all pressure data indicating significant negative values must be considered somewhat suspect.

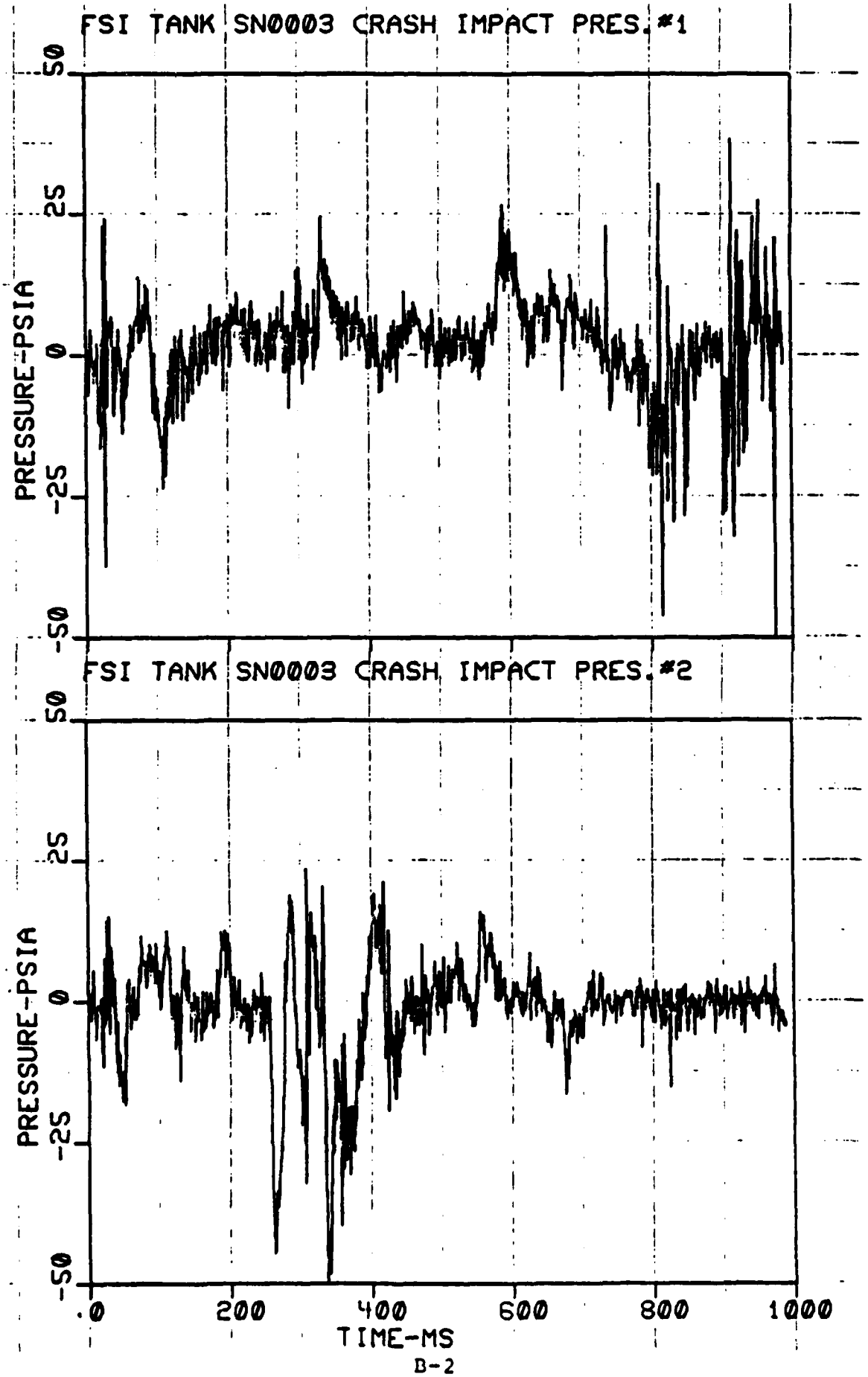
B. Strain Data - The shape of certain of the strain data traces may not appear as expected throughout each of the tests included in this series. Some degree of this occurrence is due to the relatively low strain levels experienced in each test as opposed to those anticipated when the full scale data ranges were established. The strain values actually measured in these cases are consequently in the noise band of the data acquisition system, requiring additional interpreation for analysis.

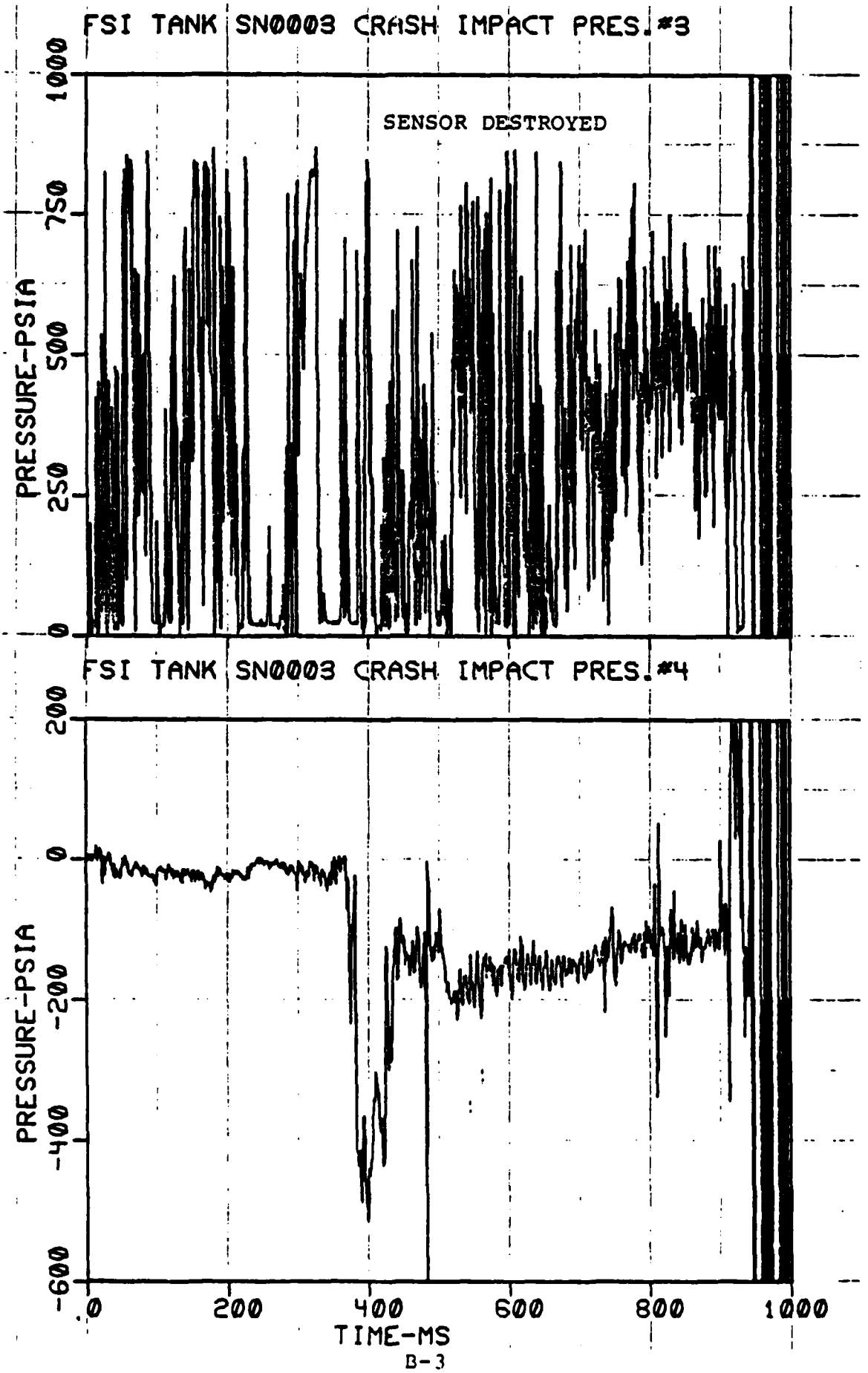
C. Time Base - The nature of these tests precluded the establishment of a definite impact time (the point of impact was undefined so that an impact switch could not be attached). Therefore, a best estimate of impact time was chosen for each of the two tracks of data based on the occurrences in the data and correlation of the data on the two tracks. The error for selection of impact time is approximately ±3 ms, and the error for correlation of data tracks is approximately ±2 ms. Therefore, the total T_o error for any given channel would be ±5 ms.

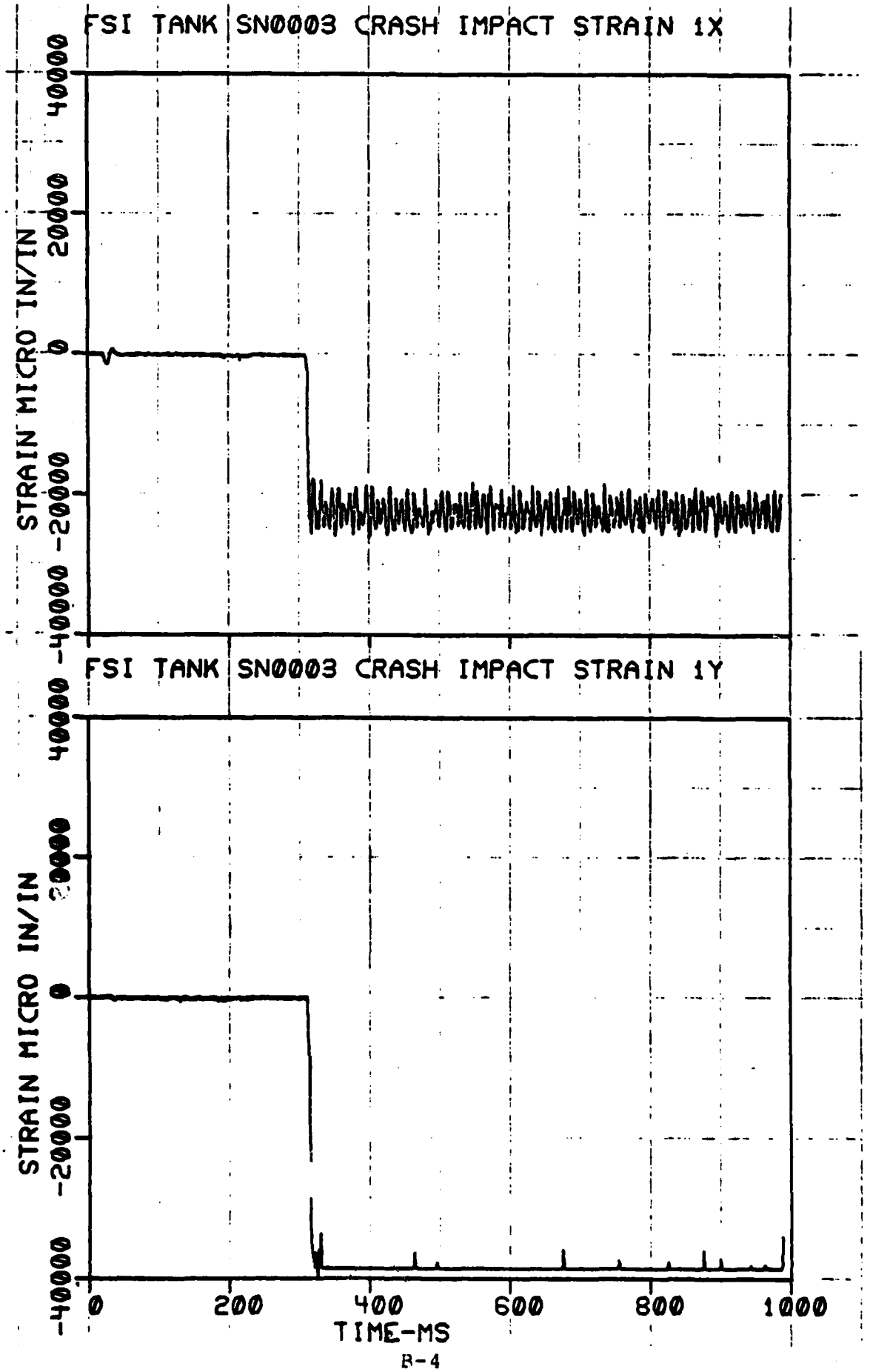
APPENDIX B

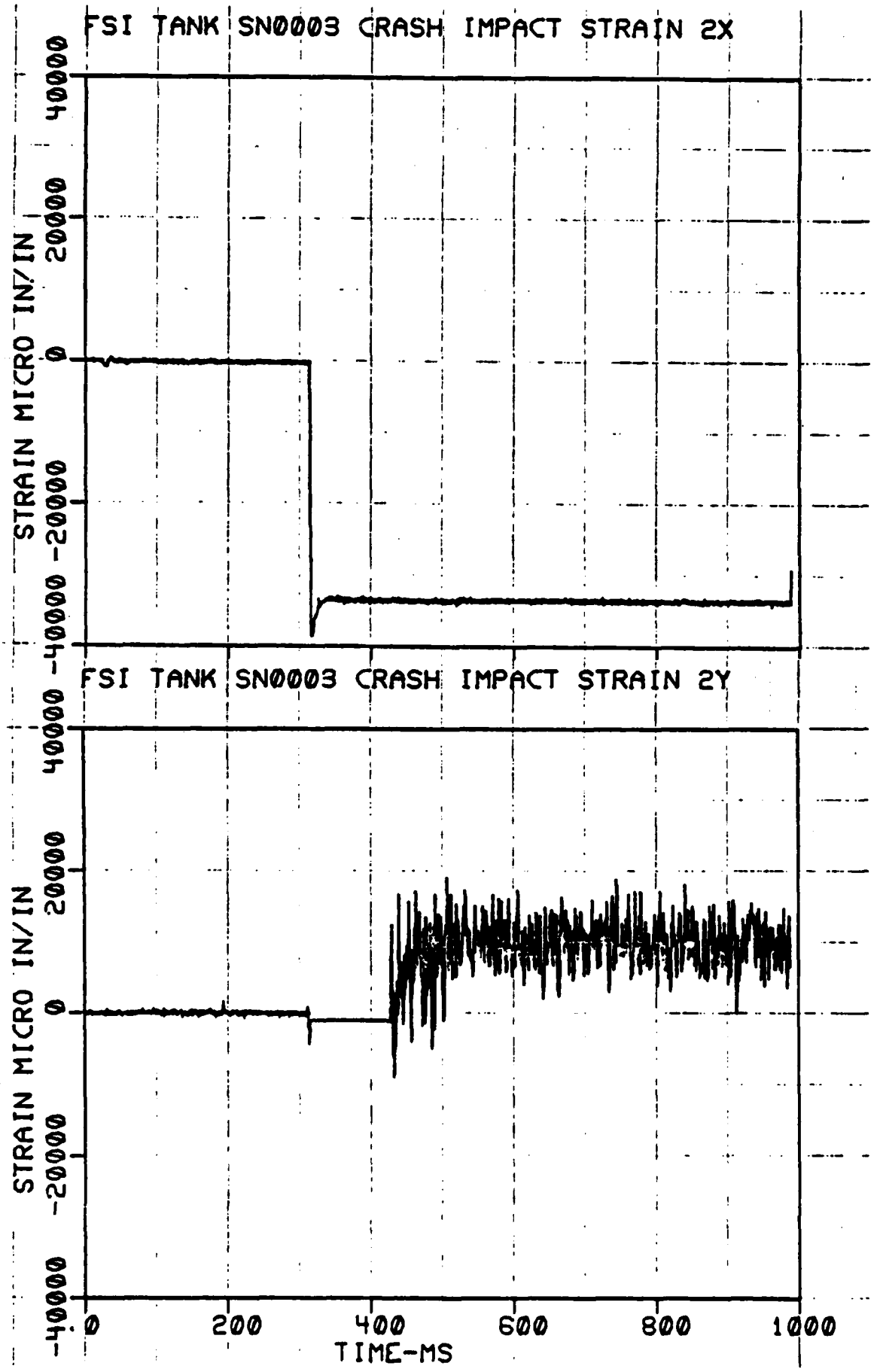
Tank SN0003

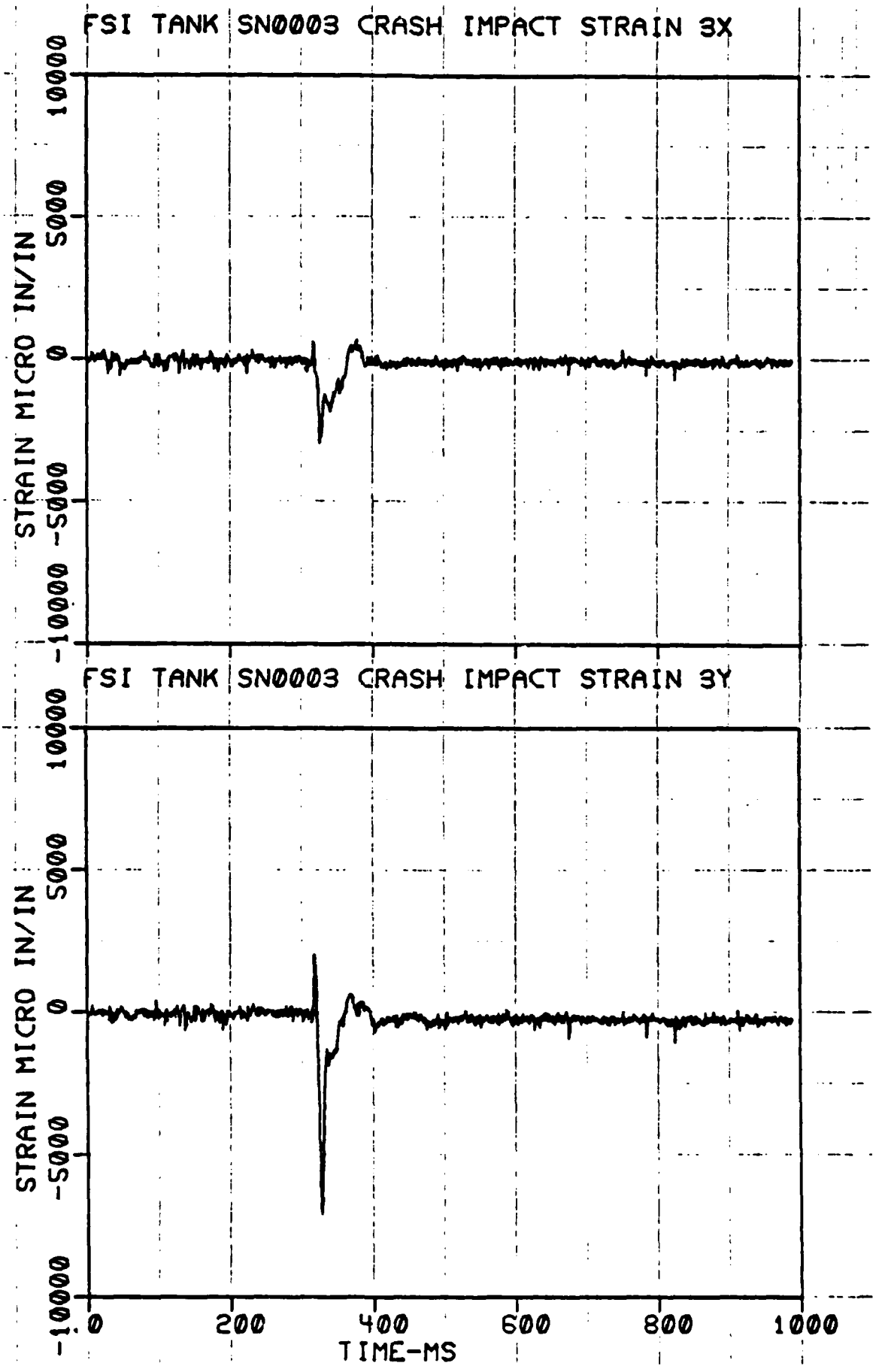
Strain and Pressure Data
Filtered at 1000 Hz
Positive Strain is Compression

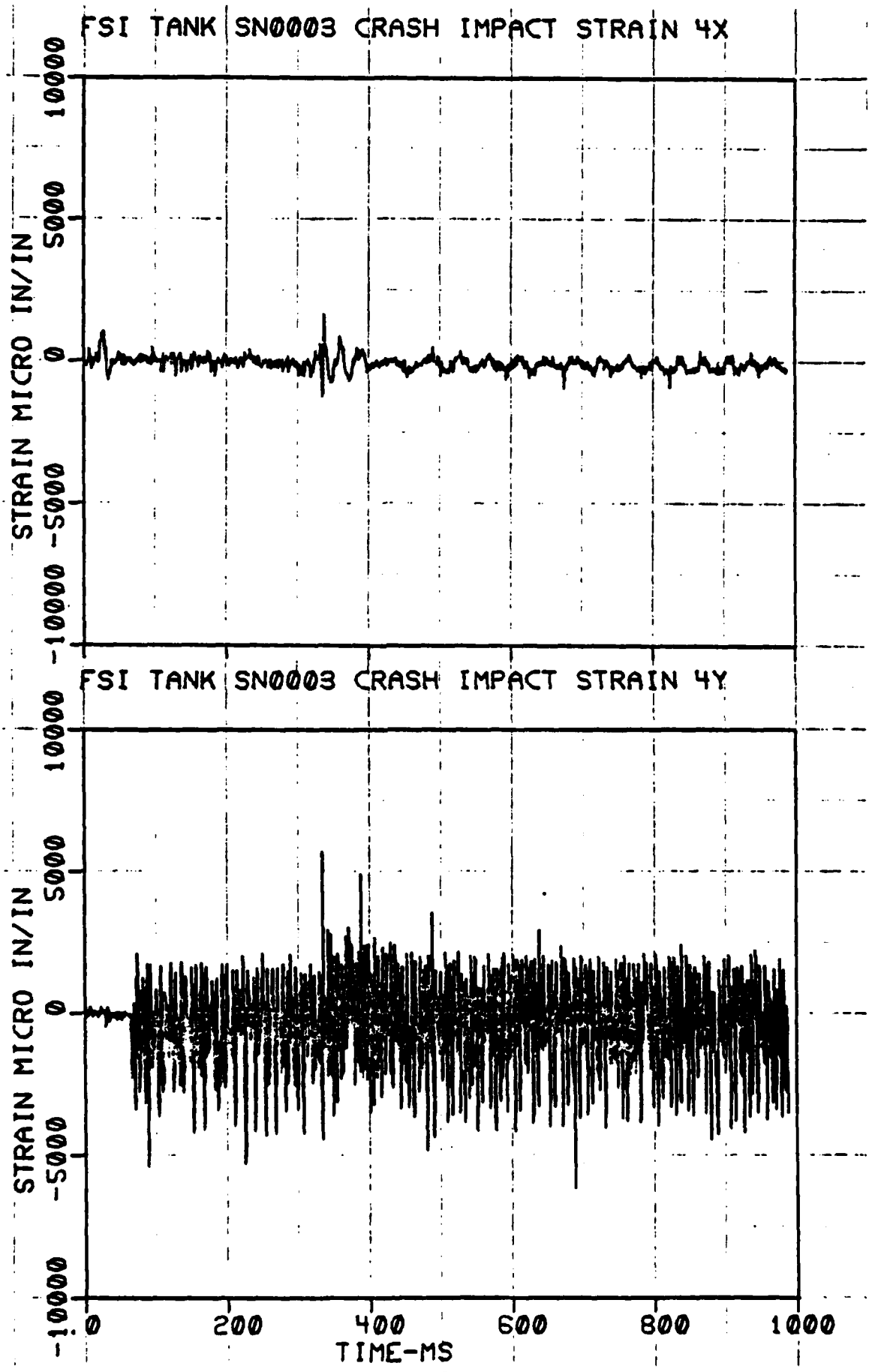

FSI TANK SN0003 CRASH IMPACT PRES. #1
50
25
0
-25
-50
PRESSURE-PSIA
FSI TANK SN0003 CRASH IMPACT PRES. #2
50
25
0
-25
-50
PRESSURE-PSIA
0
200
400
600
800
1000
TIME-MS

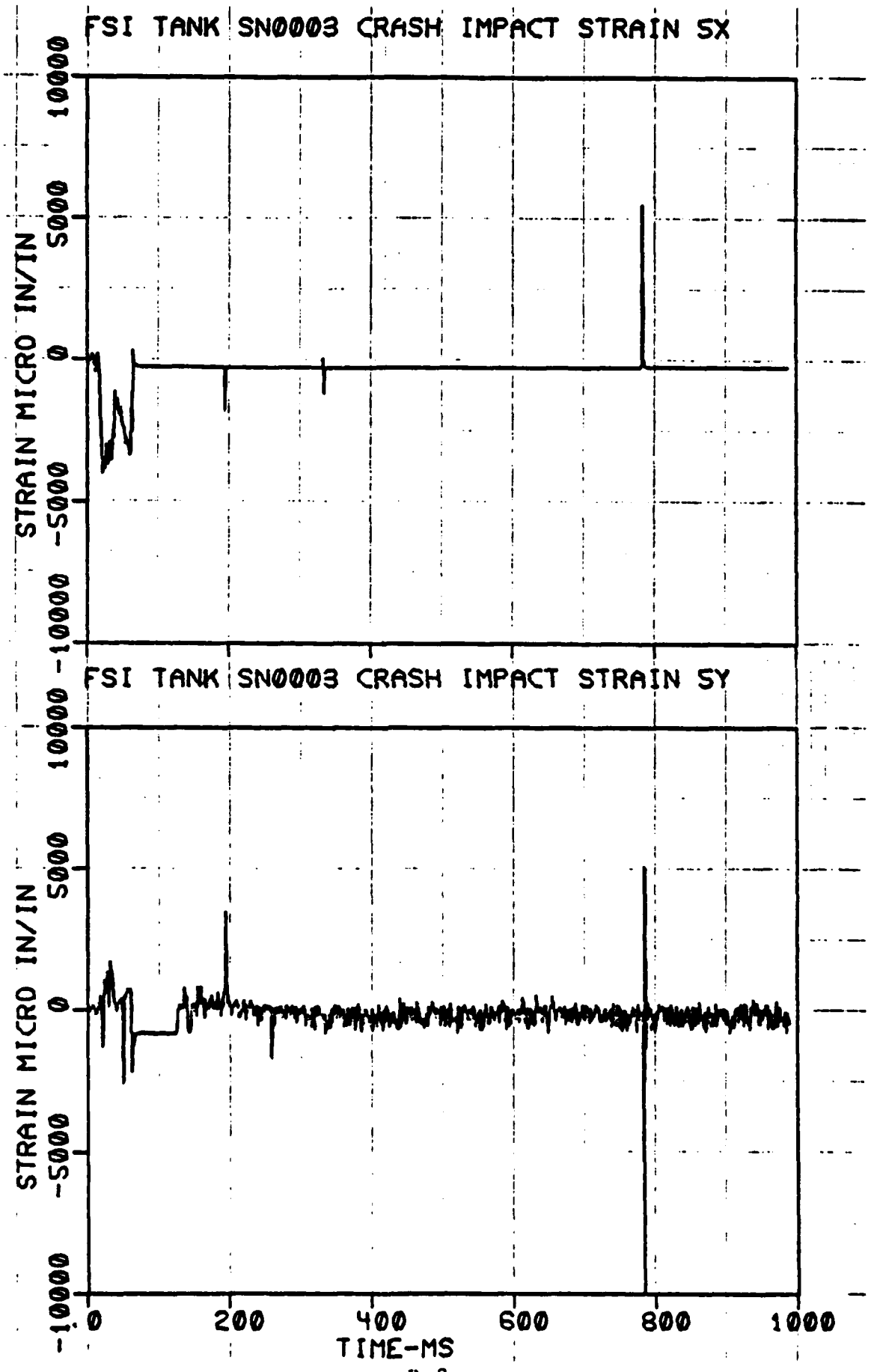

FSI TANK SN0003 CRASH IMPACT PRES. #3
SENSOR DESTROYED
PRESSURE-PSIA
1000
750
500
250
0
FSI TANK SN0003 CRASH IMPACT PRES. #4
PRESSURE-PSIA
200
0
-200
-400
-600
0
200
400
600
800
1000
TIME-MS

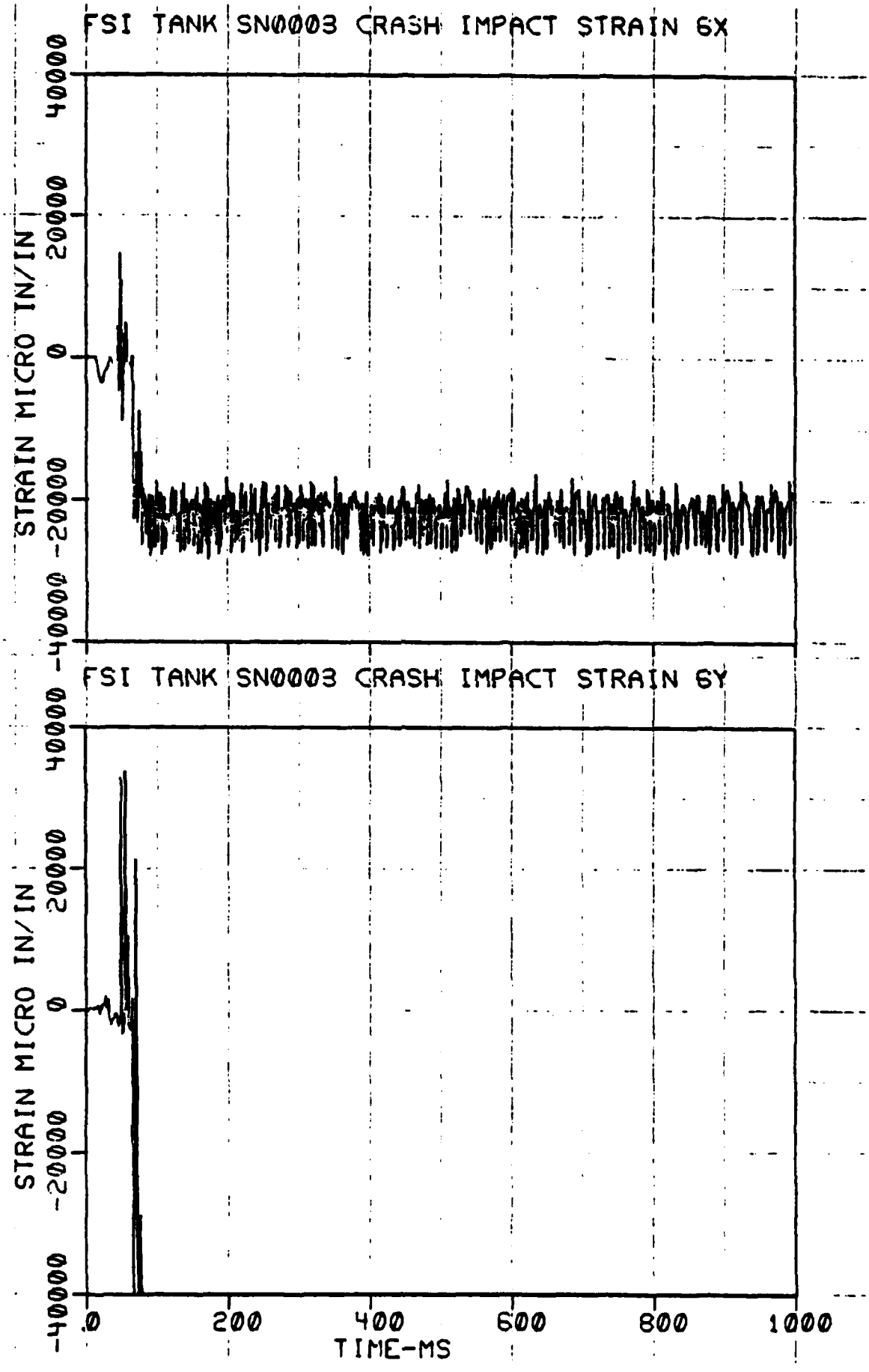

FSI TANK SN0003 CRASH IMPACT STRAIN 1X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 1Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS

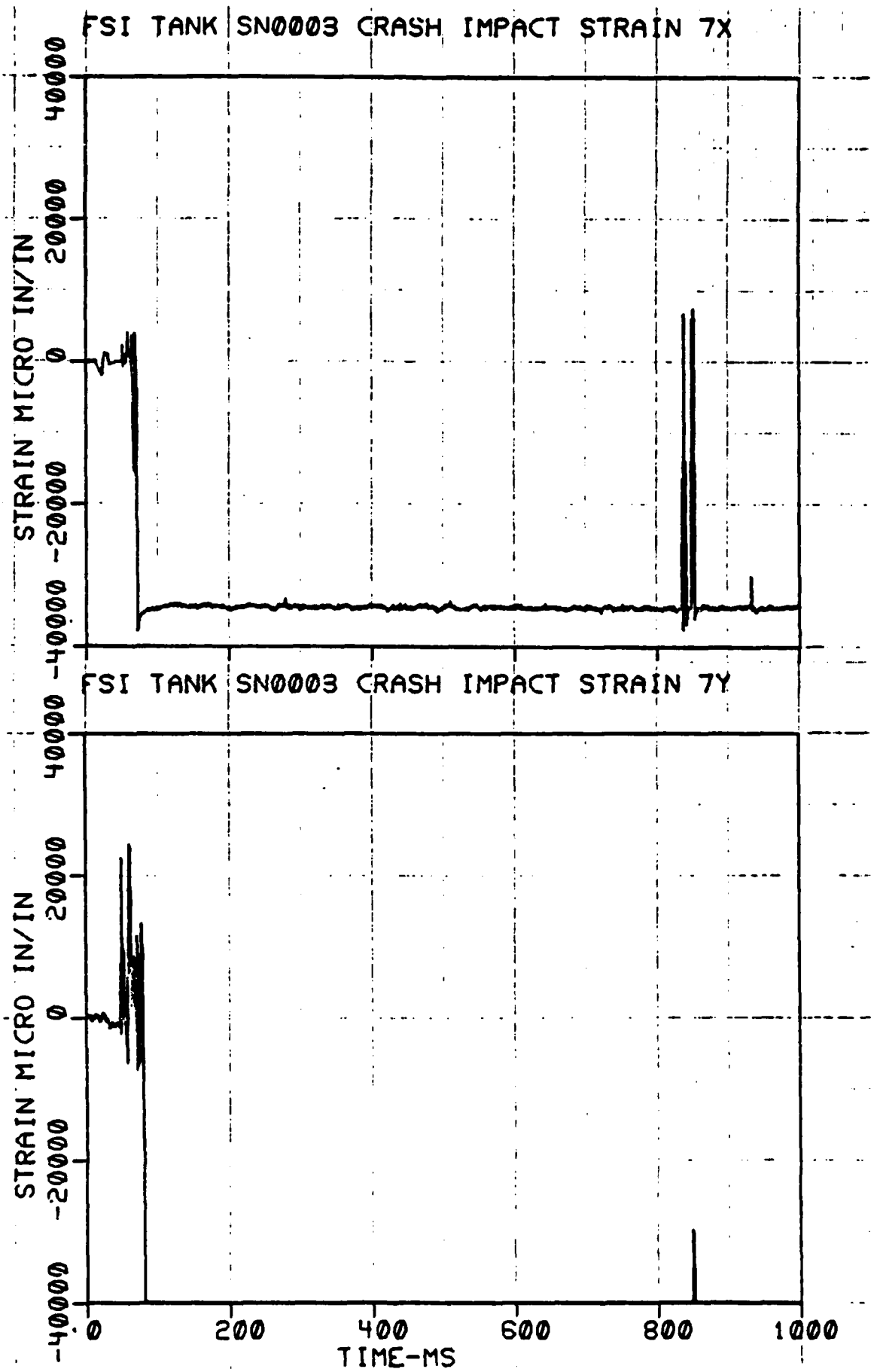

FSI TANK SN0003 CRASH IMPACT STRAIN 2X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 2Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS

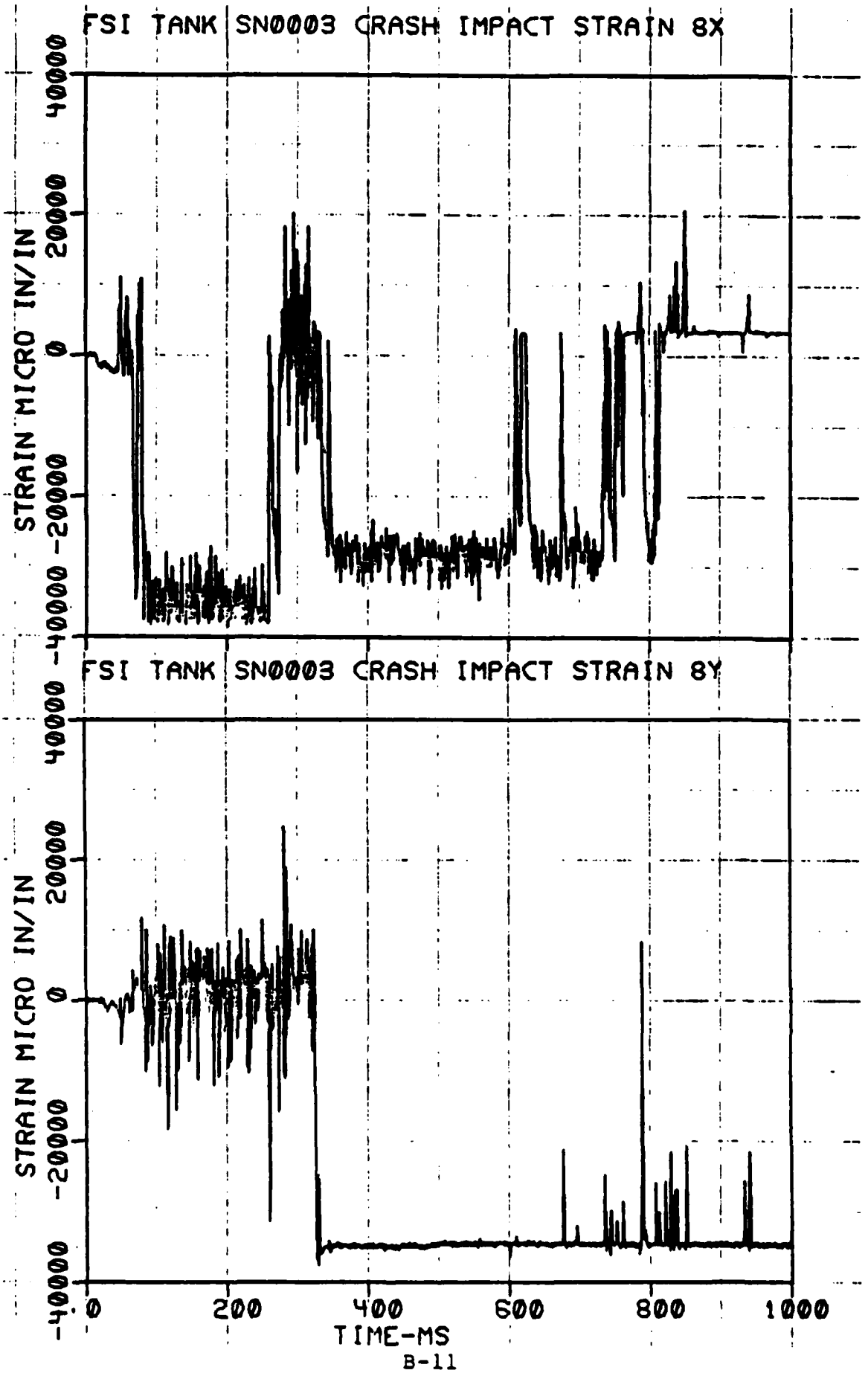

FSI TANK SN0003 CRASH IMPACT STRAIN 3X
STRAIN MICRO IN/IN
10000
5000
0
-5000
-10000
FSI TANK SN0003 CRASH IMPACT STRAIN 3Y
STRAIN MICRO IN/IN
10000
5000
0
-5000
-10000
0
200
400
600
800
1000
TIME-MS

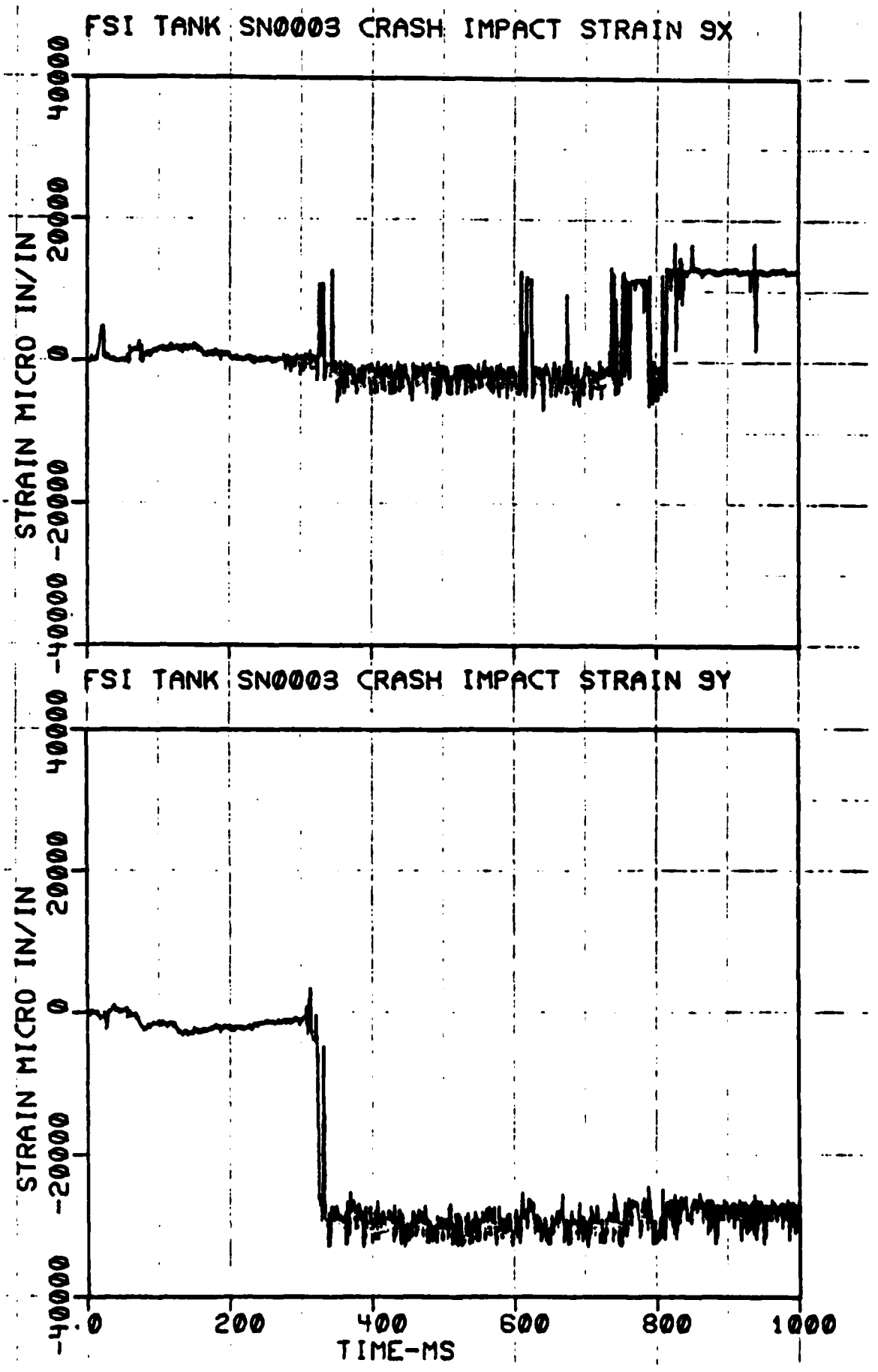

FSI TANK SN0003 CRASH IMPACT STRAIN 4X
STRAIN MICRO IN/IN
10000
5000
0
-5000
-10000
FSI TANK SN0003 CRASH IMPACT STRAIN 4Y
STRAIN MICRO IN/IN
10000
5000
0
-5000
-10000
0
200
400
600
800
1000
TIME-MS

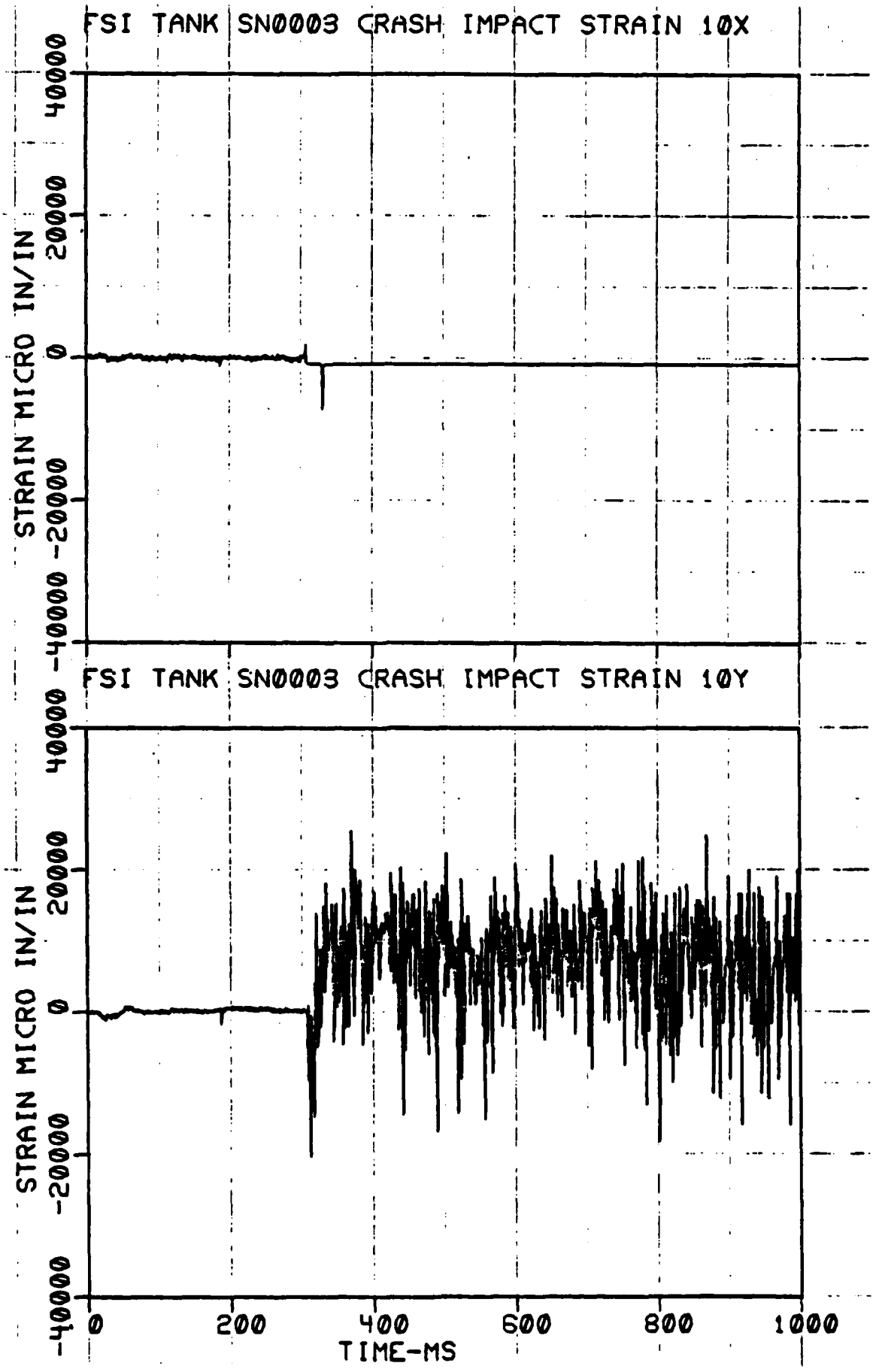

FSI TANK SN0003 CRASH IMPACT STRAIN SX
STRAIN MICRO IN/IN
10000
5000
0
-5000
-10000
FSI TANK SN0003 CRASH IMPACT STRAIN SY
STRAIN MICRO IN/IN
10000
5000
0
-5000
-10000
0
200
400
600
800
1000
TIME-MS


FSI TANK SN0003 CRASH IMPACT STRAIN 6X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 6Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS


FSI TANK SN0003 CRASH IMPACT STRAIN 7X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 7Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS


FSI TANK SN0003 CRASH IMPACT STRAIN 8X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 8Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS

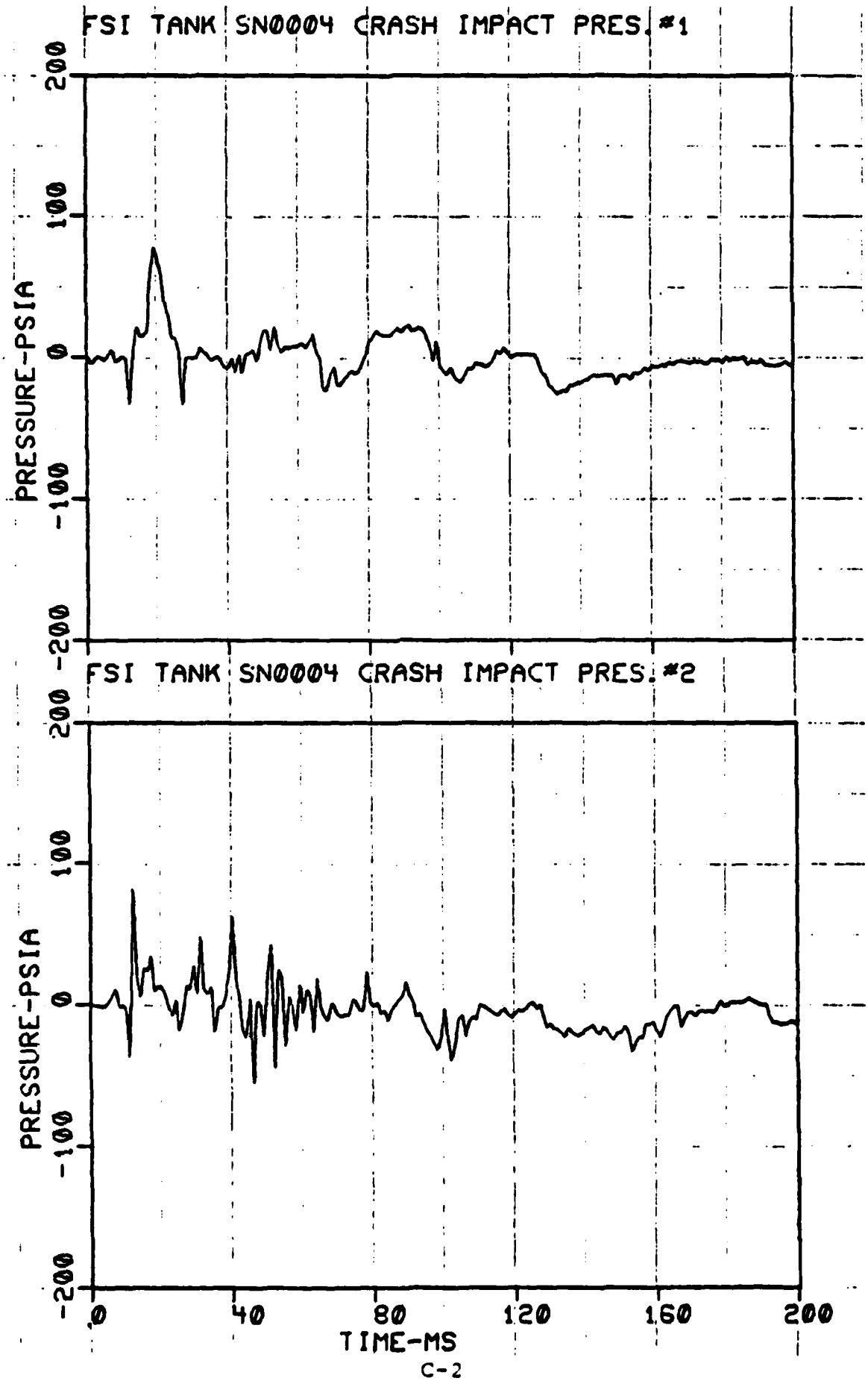

FSI TANK SN0003 CRASH IMPACT STRAIN 9X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 9Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS

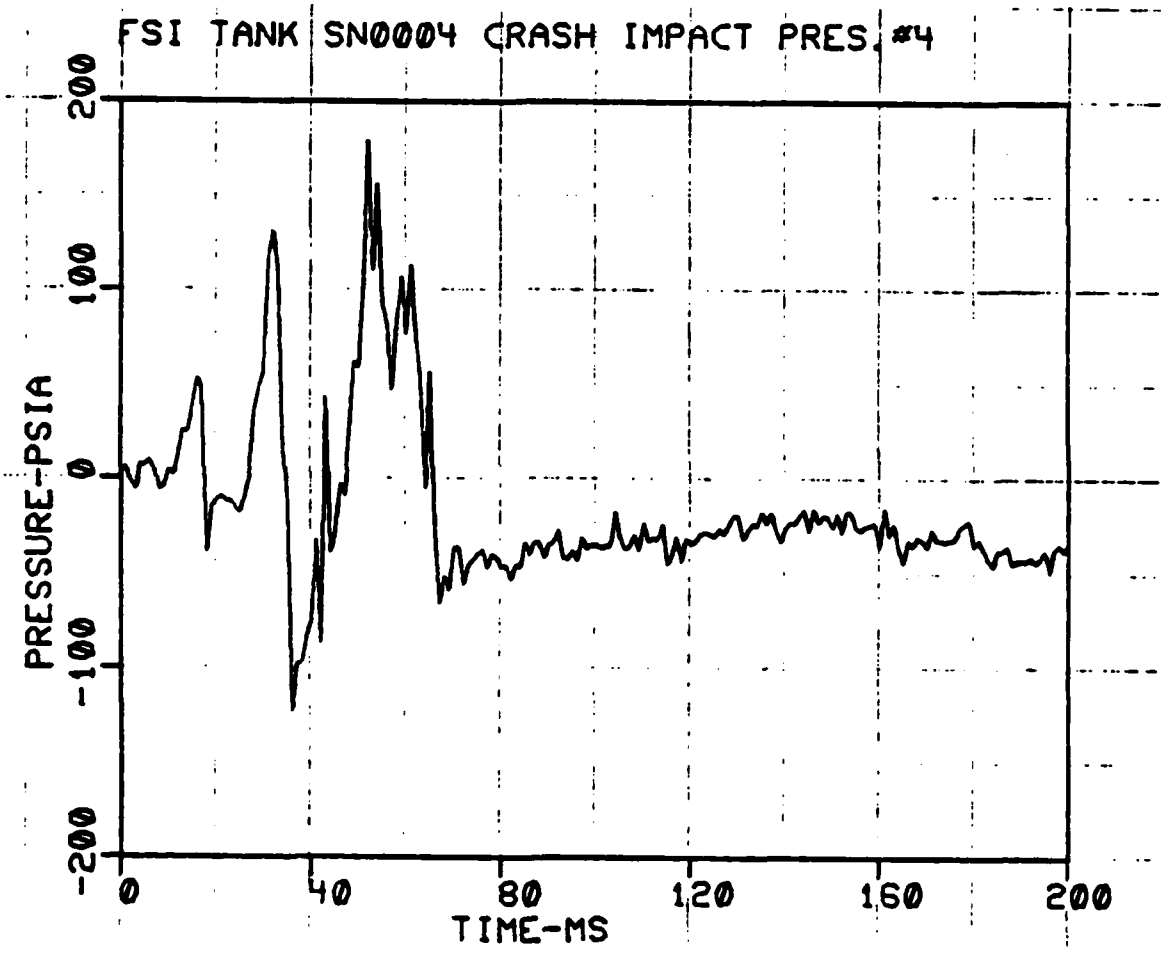

FSI TANK SN0003 CRASH IMPACT STRAIN 10X
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0003 CRASH IMPACT STRAIN 10Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
0
200
400
600
800
1000
TIME-MS

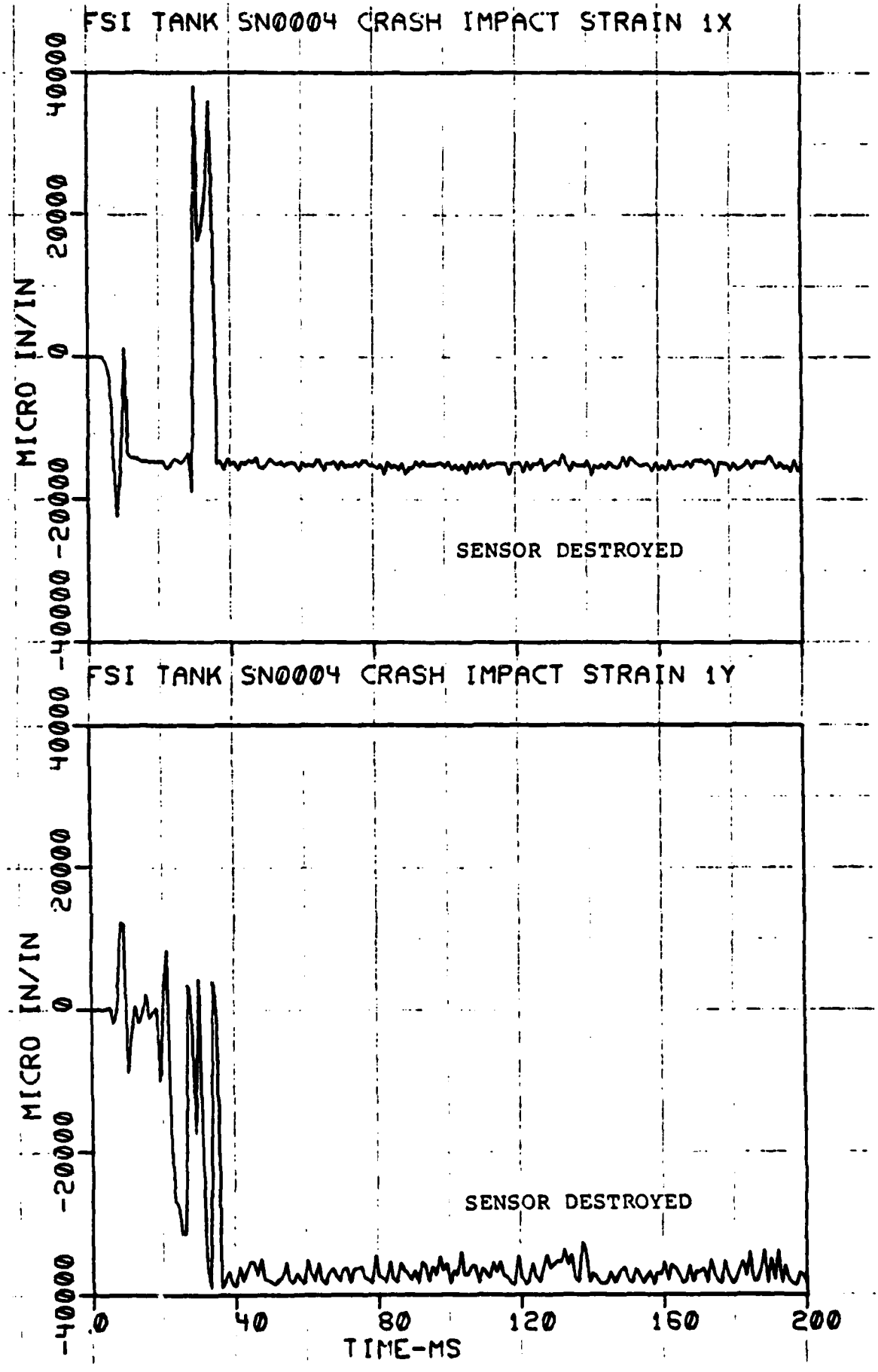
APPENDIX C

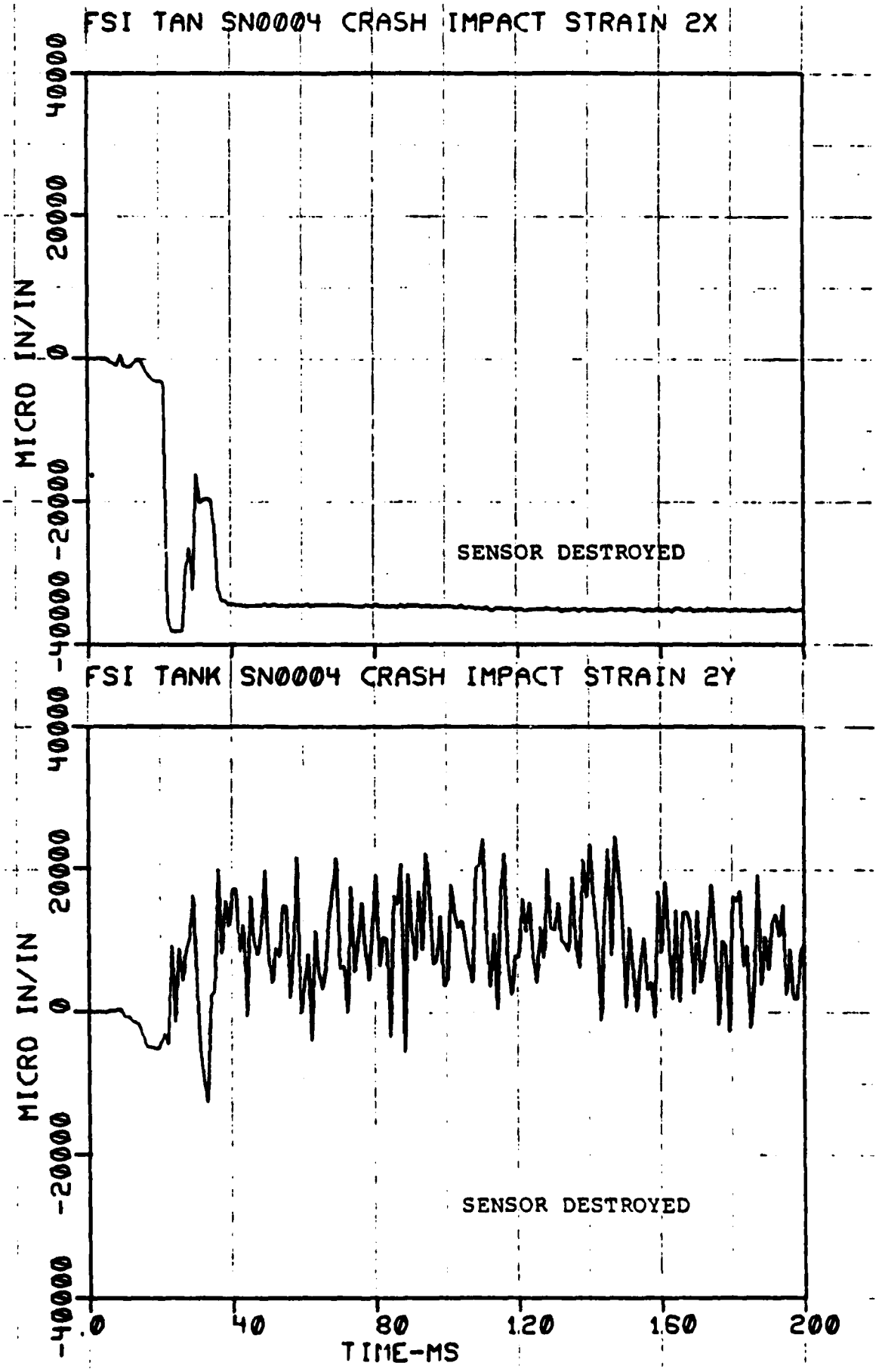
Tank SN0004

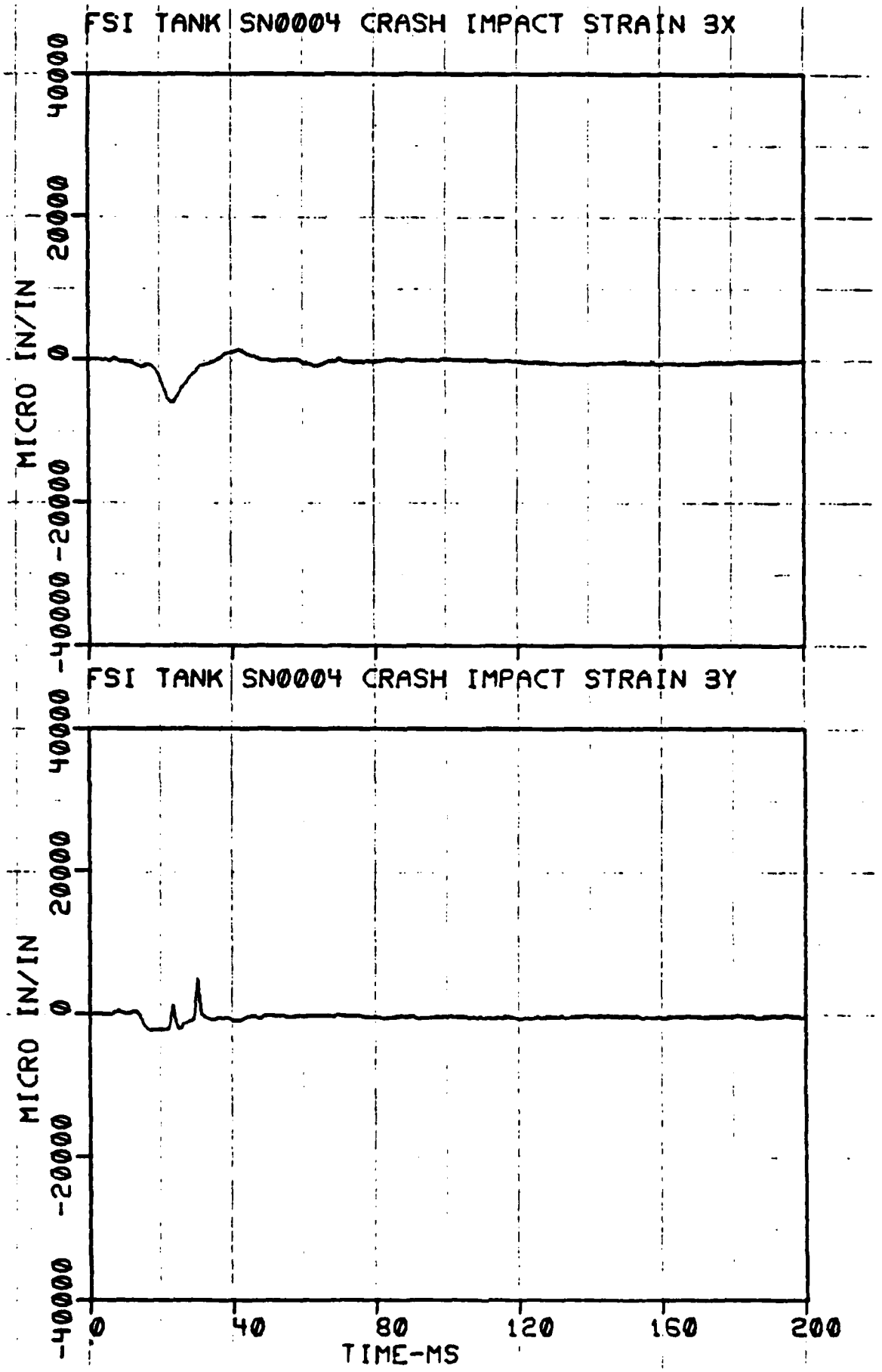
Strain and Pressure Data
Filtered at 1000 Hz
Positive Strain is Compression

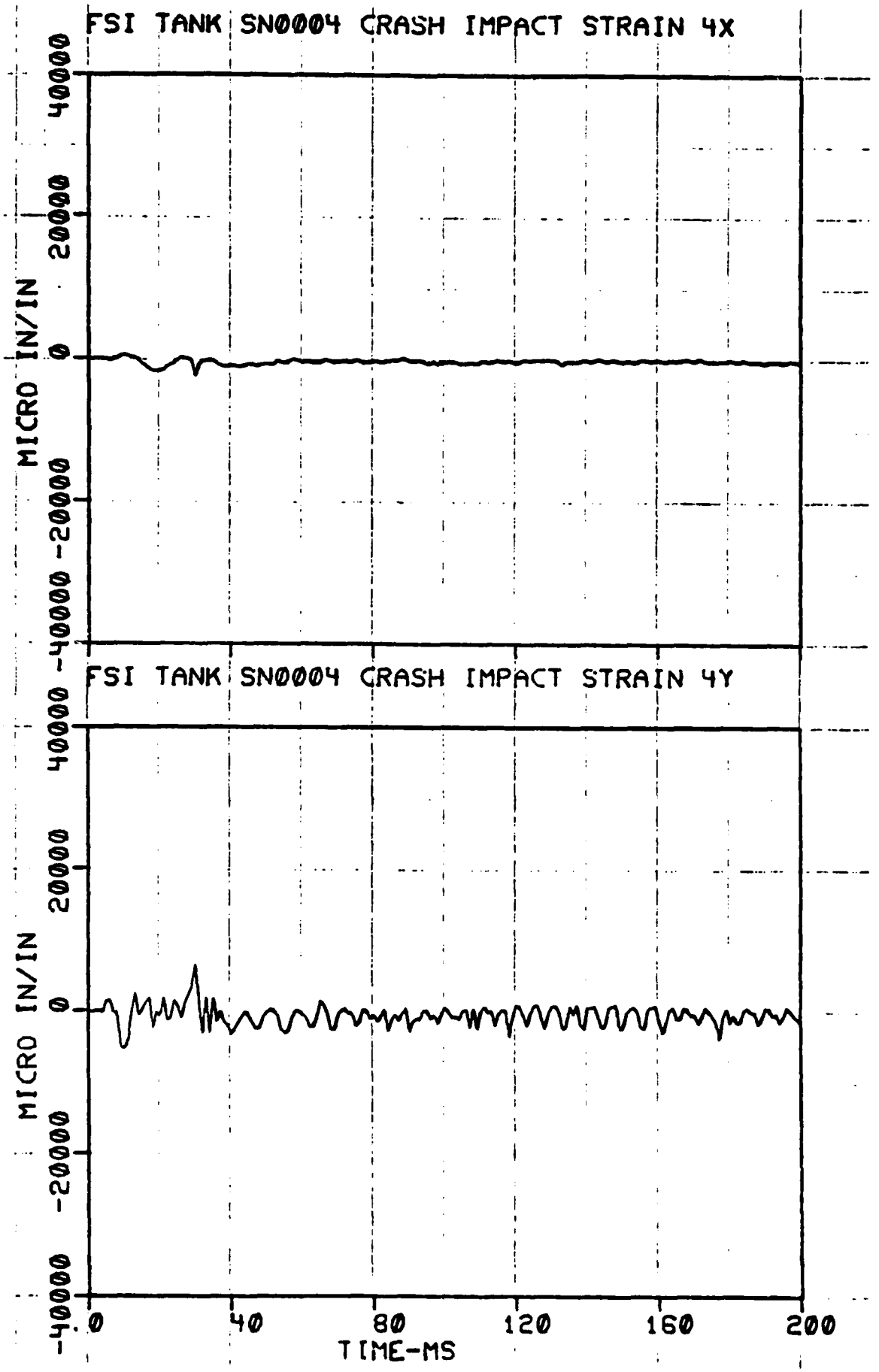

FSI TANK SN0004 CRASH IMPACT PRES. #1
200
100
0
-100
-200
PRESSURE-PSIA
FSI TANK SN0004 CRASH IMPACT PRES. #2
200
100
0
-100
-200
PRESSURE-PSIA
0
40
80
120
160
200
TIME-MS

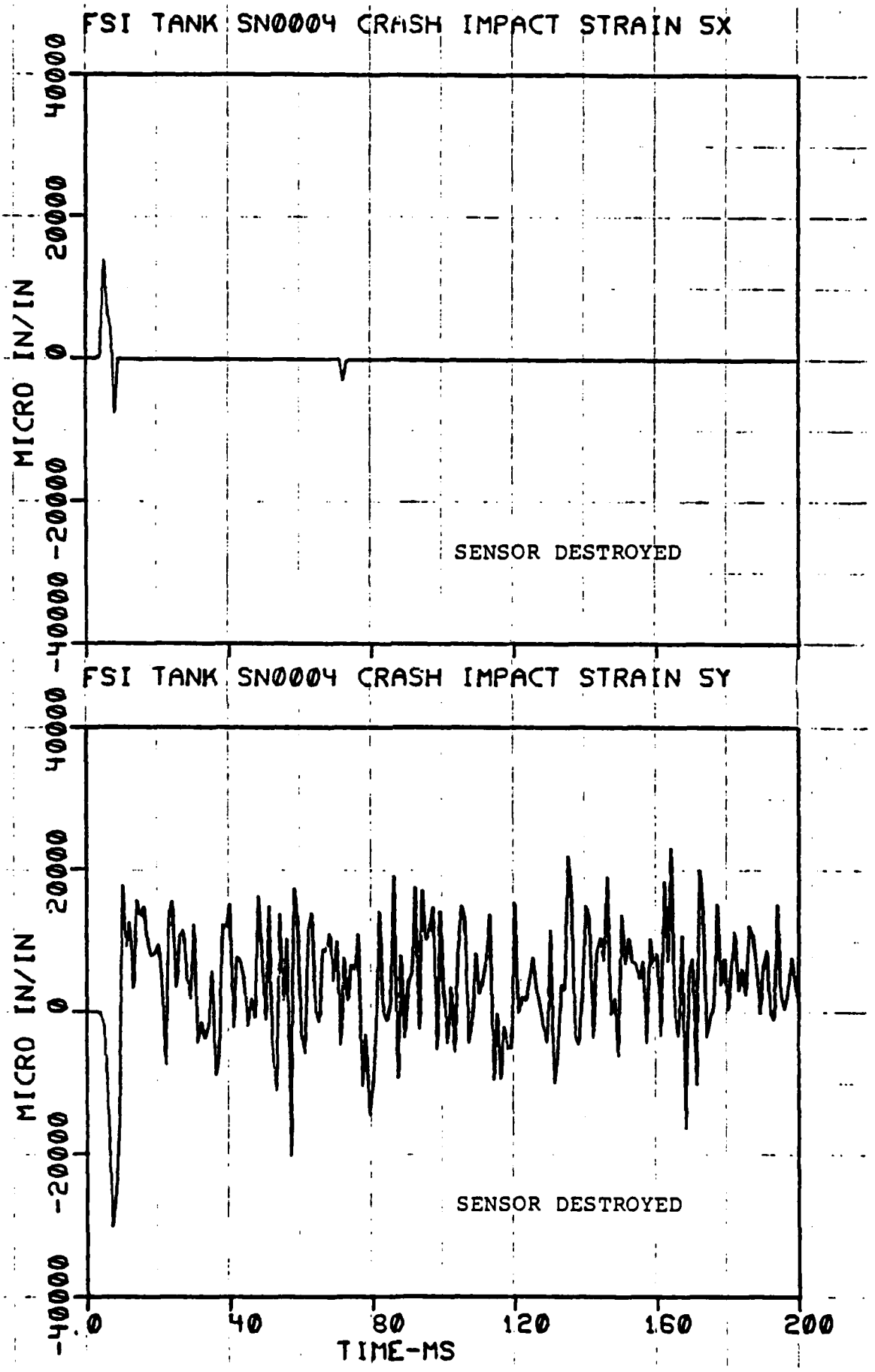

FSI TANK SN0004 CRASH IMPACT PRES. #4
PRESSURE-PSIA
200
100
0
-100
-200
0
40
80
120
160
200
TIME-MS

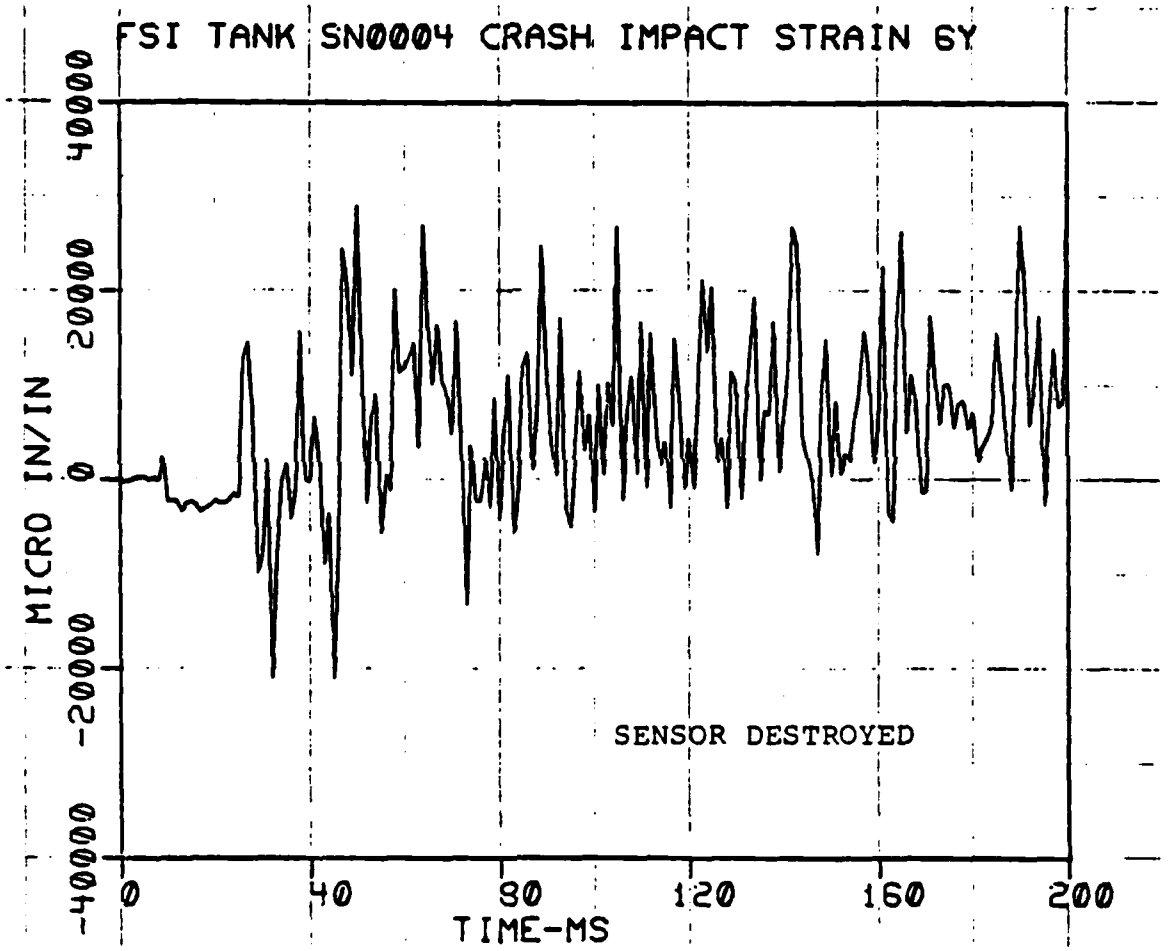

FSI TANK SN0004 CRASH IMPACT STRAIN 1X
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
FSI TANK SN0004 CRASH IMPACT STRAIN 1Y
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
0
40
80
120
160
200
TIME-MS

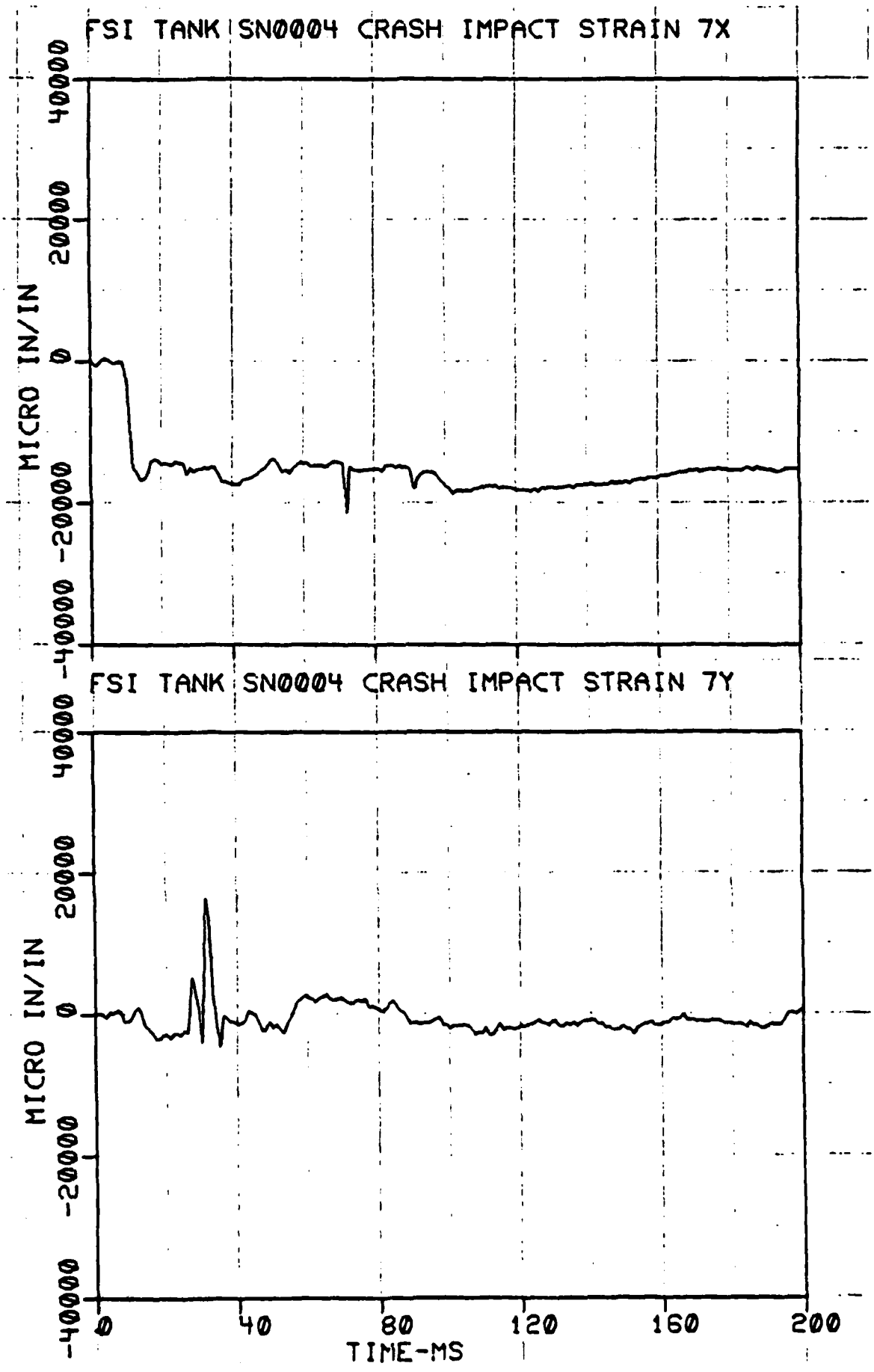

FSI TAN SN0004 CRASH IMPACT STRAIN 2X
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
FSI TANK SN0004 CRASH IMPACT STRAIN 2Y
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
0
40
80
120
160
200
TIME-MS

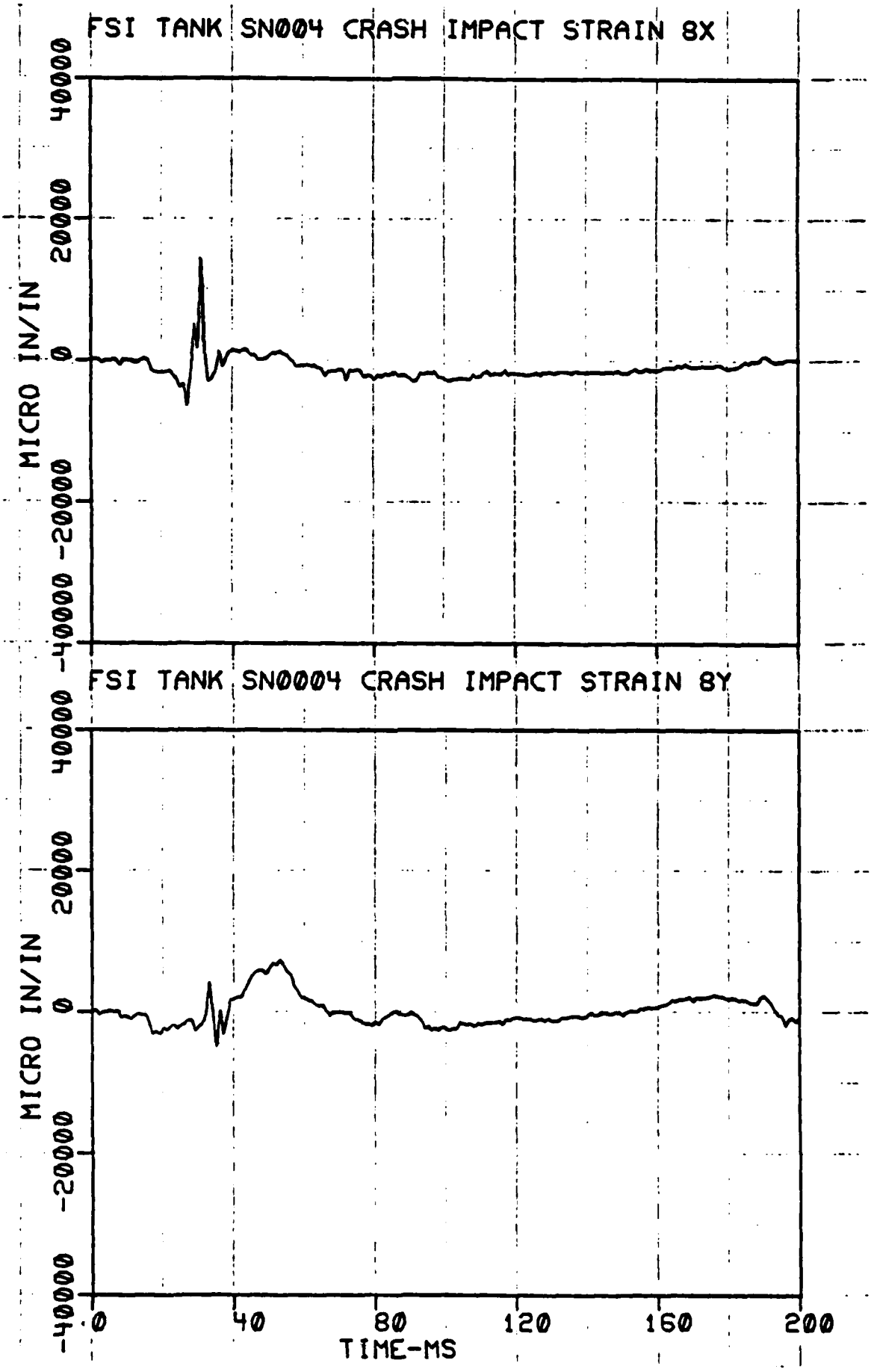

FSI TANK SN0004 CRASH IMPACT STRAIN 3X
MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0004 CRASH IMPACT STRAIN 3Y
MICRO IN/IN
40000
20000
0
-20000
-40000
0
40
80
120
160
200
TIME-MS

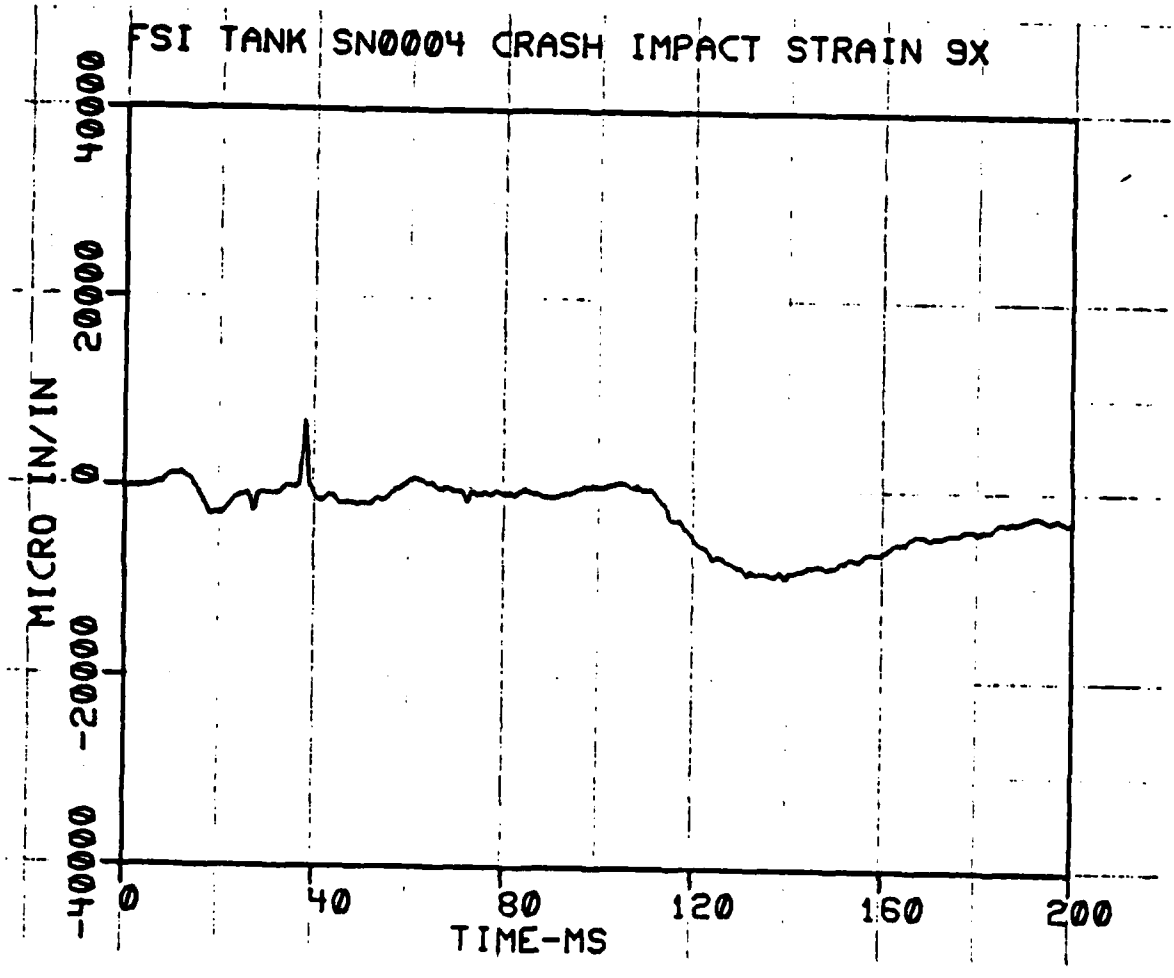

FSI TANK SN0004 CRASH IMPACT STRAIN 4X
MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0004 CRASH IMPACT STRAIN 4Y
MICRO IN/IN
40000
20000
0
-20000
-40000
0
40
80
120
160
200
TIME-MS

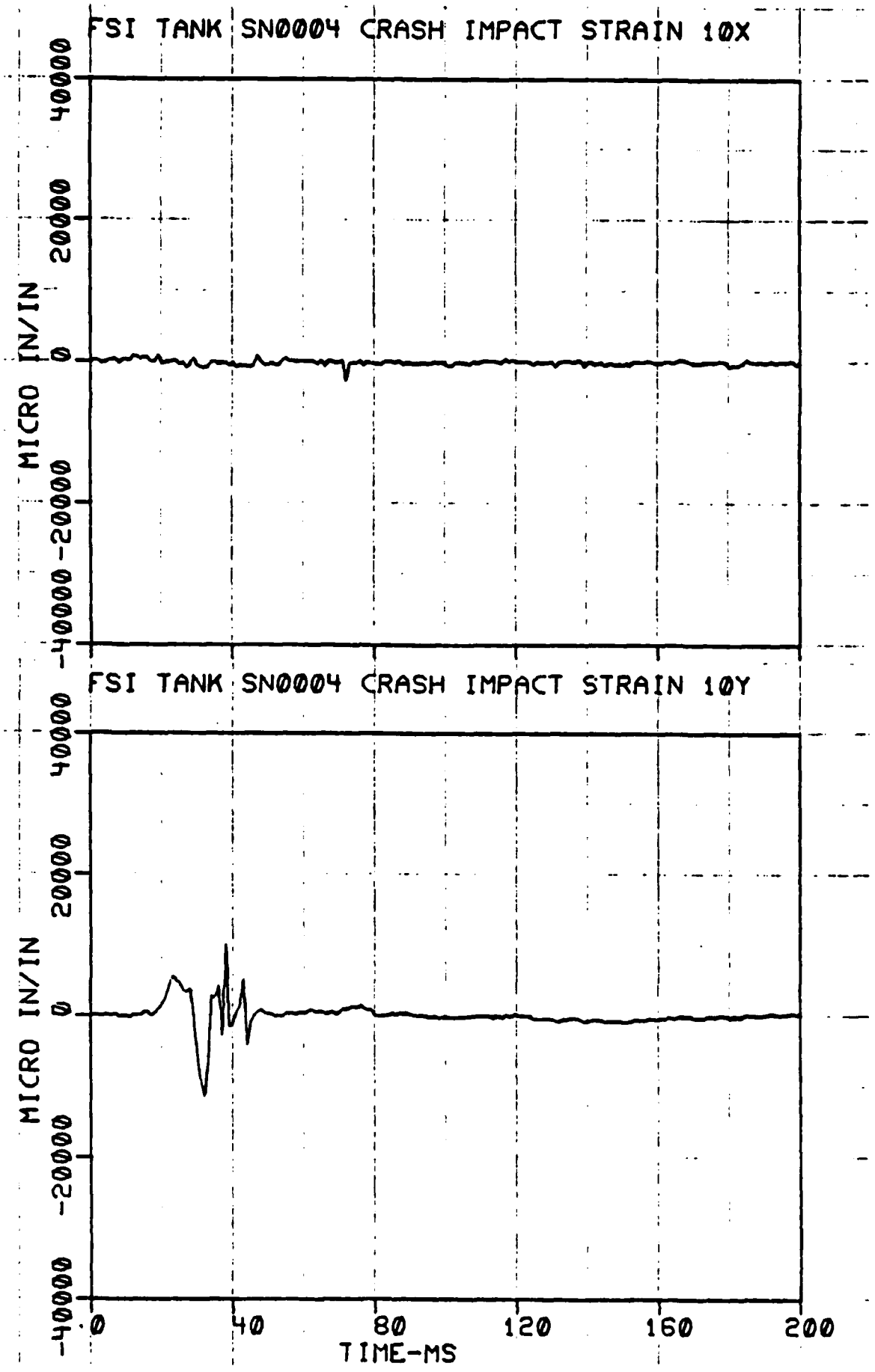

FSI TANK SN0004 CRASH IMPACT STRAIN SX
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
FSI TANK SN0004 CRASH IMPACT STRAIN SY
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
0
40
80
120
160
200
TIME-MS


FSI TANK SN0004 CRASH IMPACT STRAIN GY
MICRO IN/IN
40000
20000
0
-20000
-40000
SENSOR DESTROYED
0
40
80
120
160
200
TIME-MS


FSI TANK SN0004 CRASH IMPACT STRAIN 7X
MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0004 CRASH IMPACT STRAIN 7Y
MICRO IN/IN
40000
20000
0
-20000
-40000
0
40
80
120
160
200
TIME-MS


FSI TANK SN004 CRASH IMPACT STRAIN 8X
MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0004 CRASH IMPACT STRAIN 8Y
MICRO IN/IN
40000
20000
0
-20000
-40000
0
40
80
120
160
200
TIME-MS


FSI TANK SN0004 CRASH IMPACT STRAIN 9X
MICRO IN/IN
40000
20000
0
-20000
-40000
0
40
80
120
160
200
TIME-MS


FSI TANK SN0004 CRASH IMPACT STRAIN 10X
MICRO IN/IN
40000
20000
0
-20000
-40000
FSI TANK SN0004 CRASH IMPACT STRAIN 10Y
MICRO IN/IN
40000
20000
0
-20000
-40000
0
40
80
120
160
200
TIME-MS

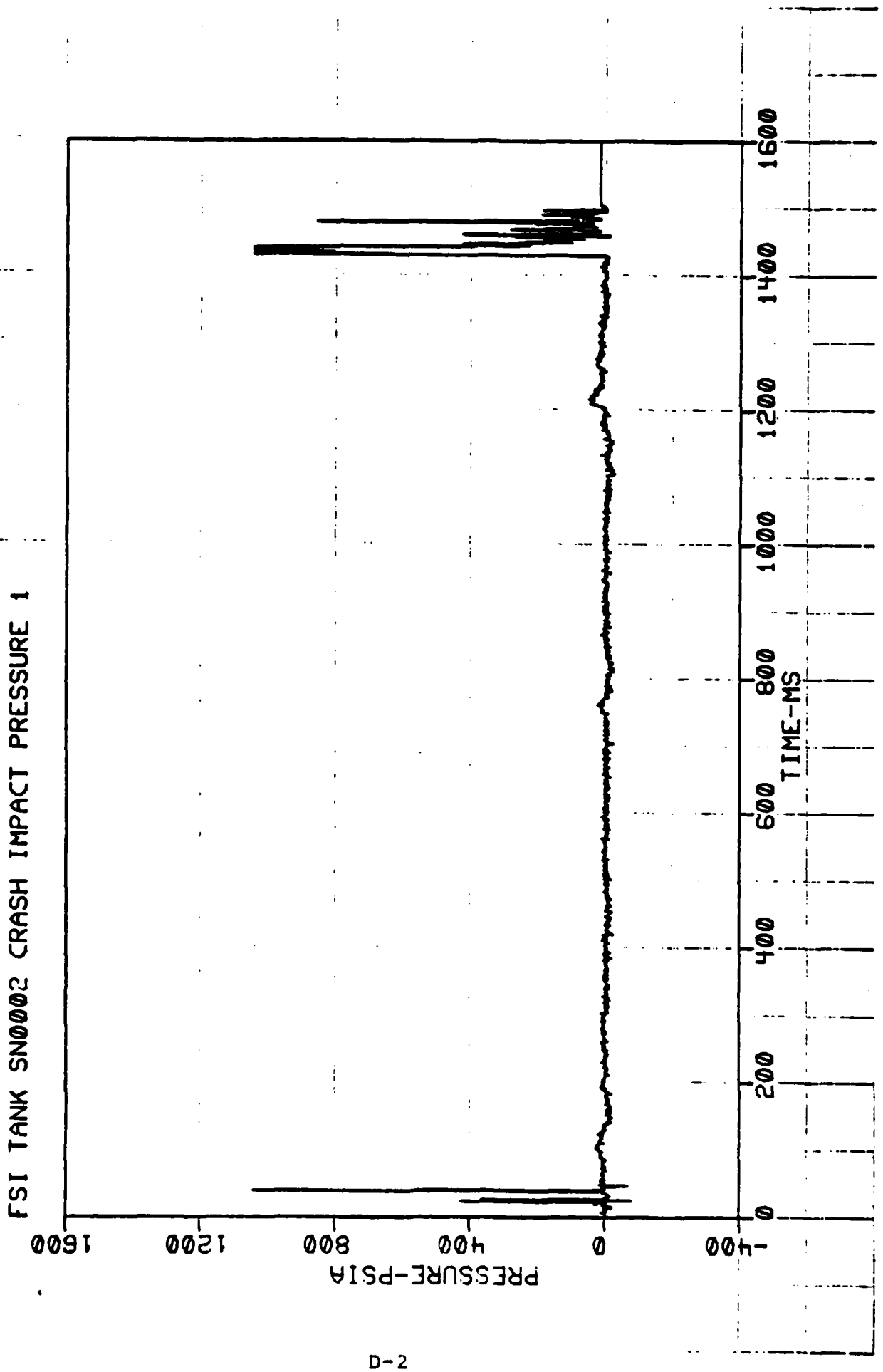
Appendix D

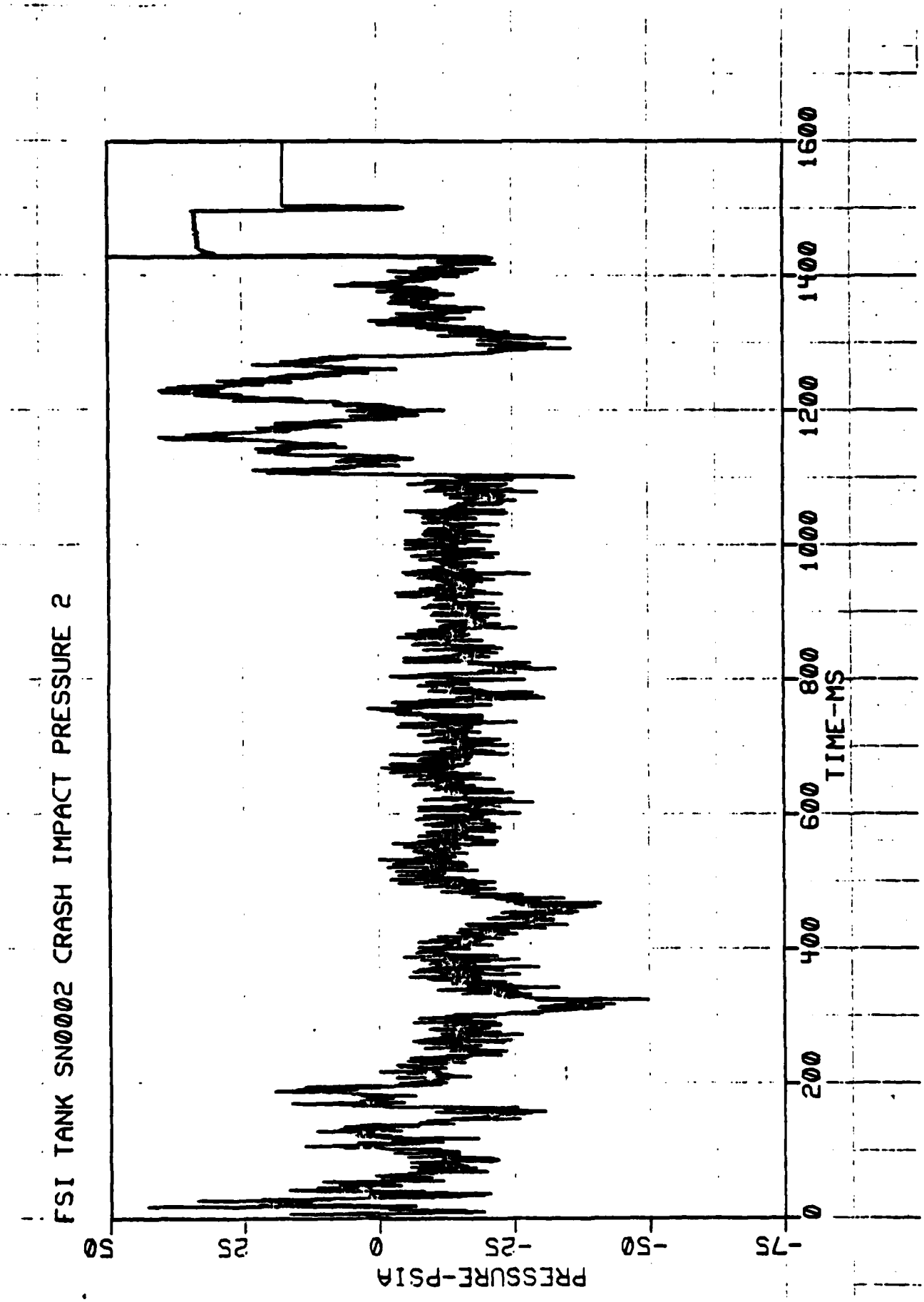
Tank SN0002

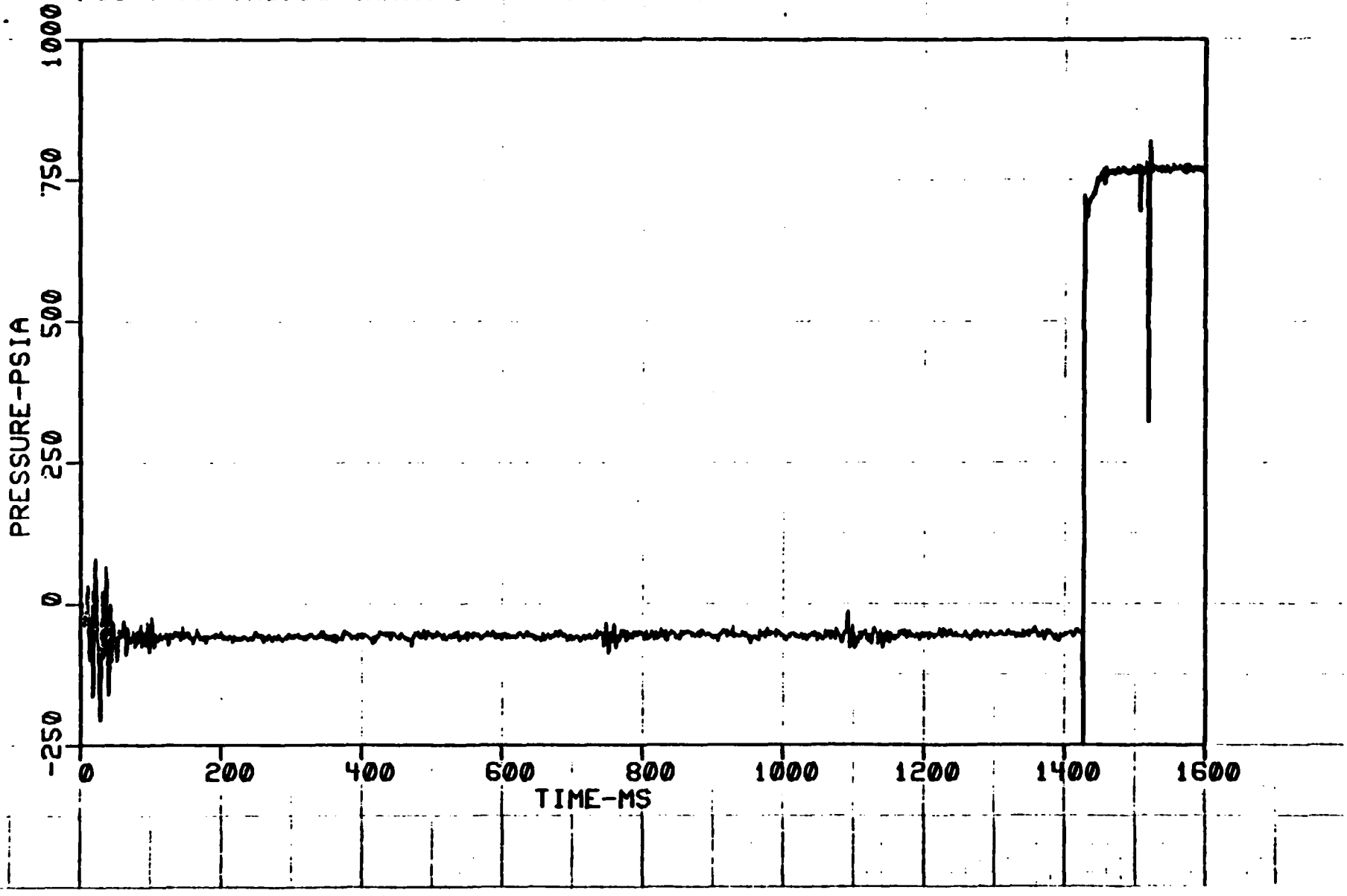
Strain and Pressure Data
Filtered at 1000 Hz
Positive Strain is Compression

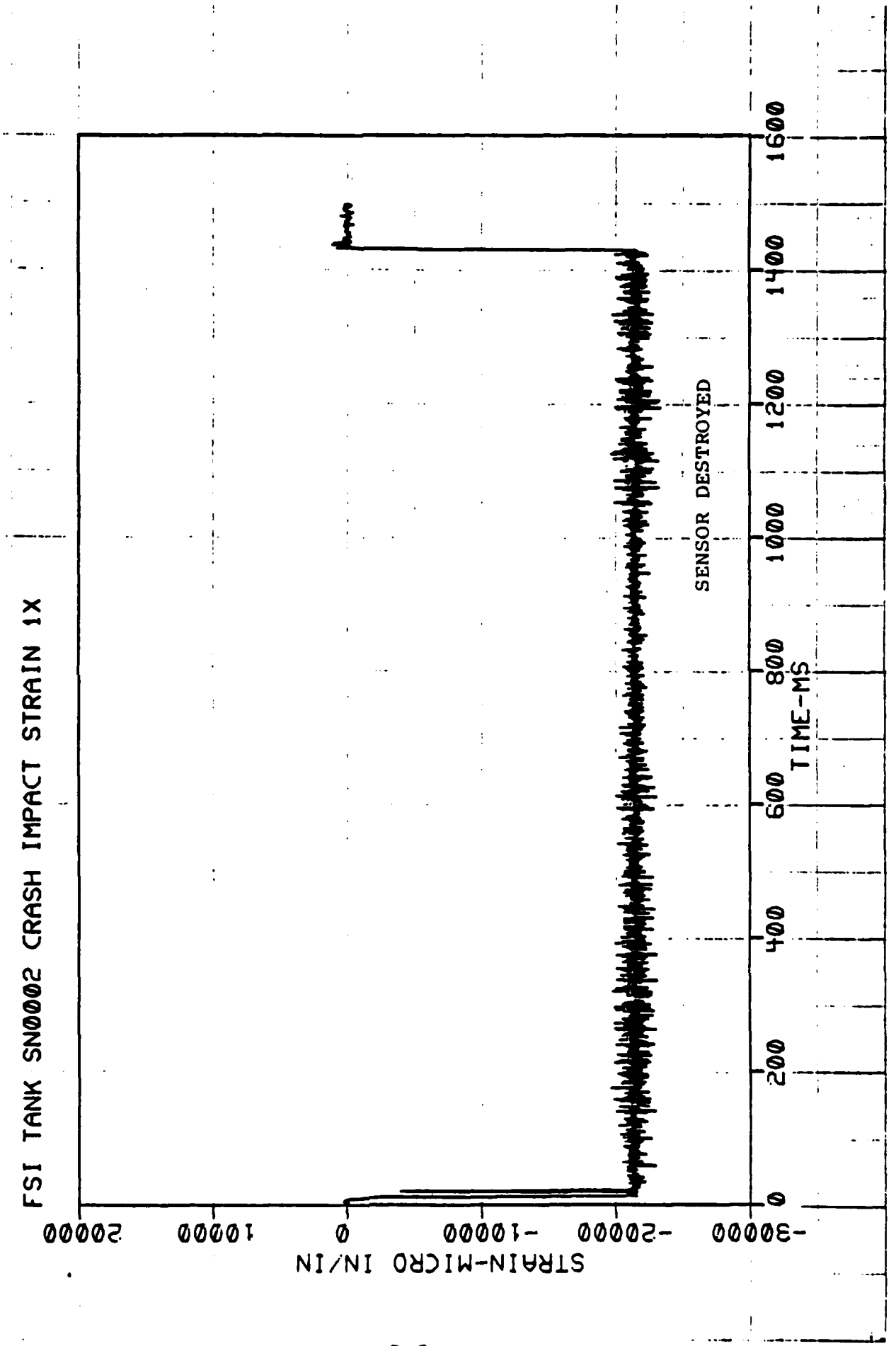
Accelerometer Data
Filtered at 100 Hz
Positive Acceleration is Upward

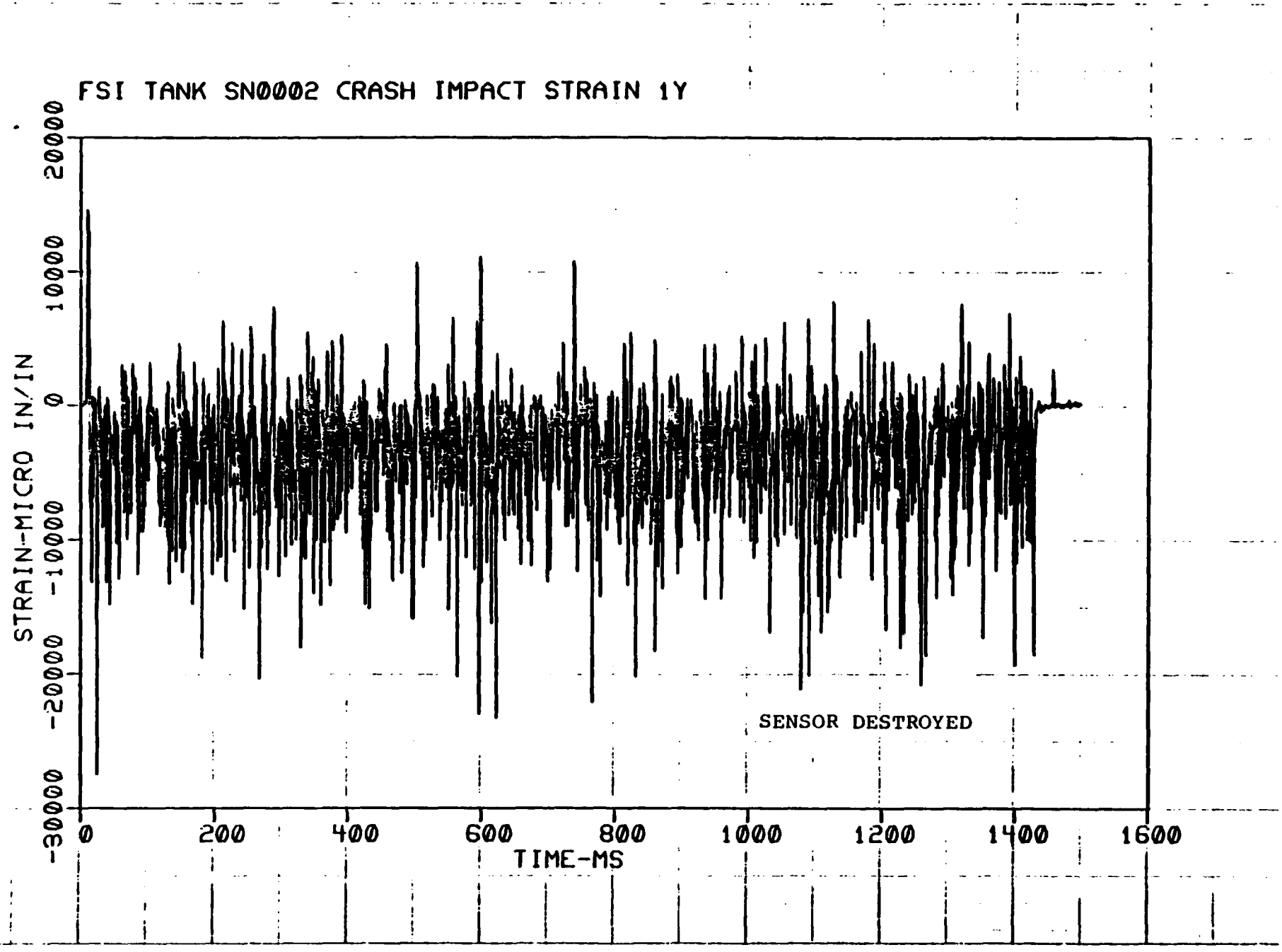
Spike at 1420-1440ms is Umbilical Disconnect

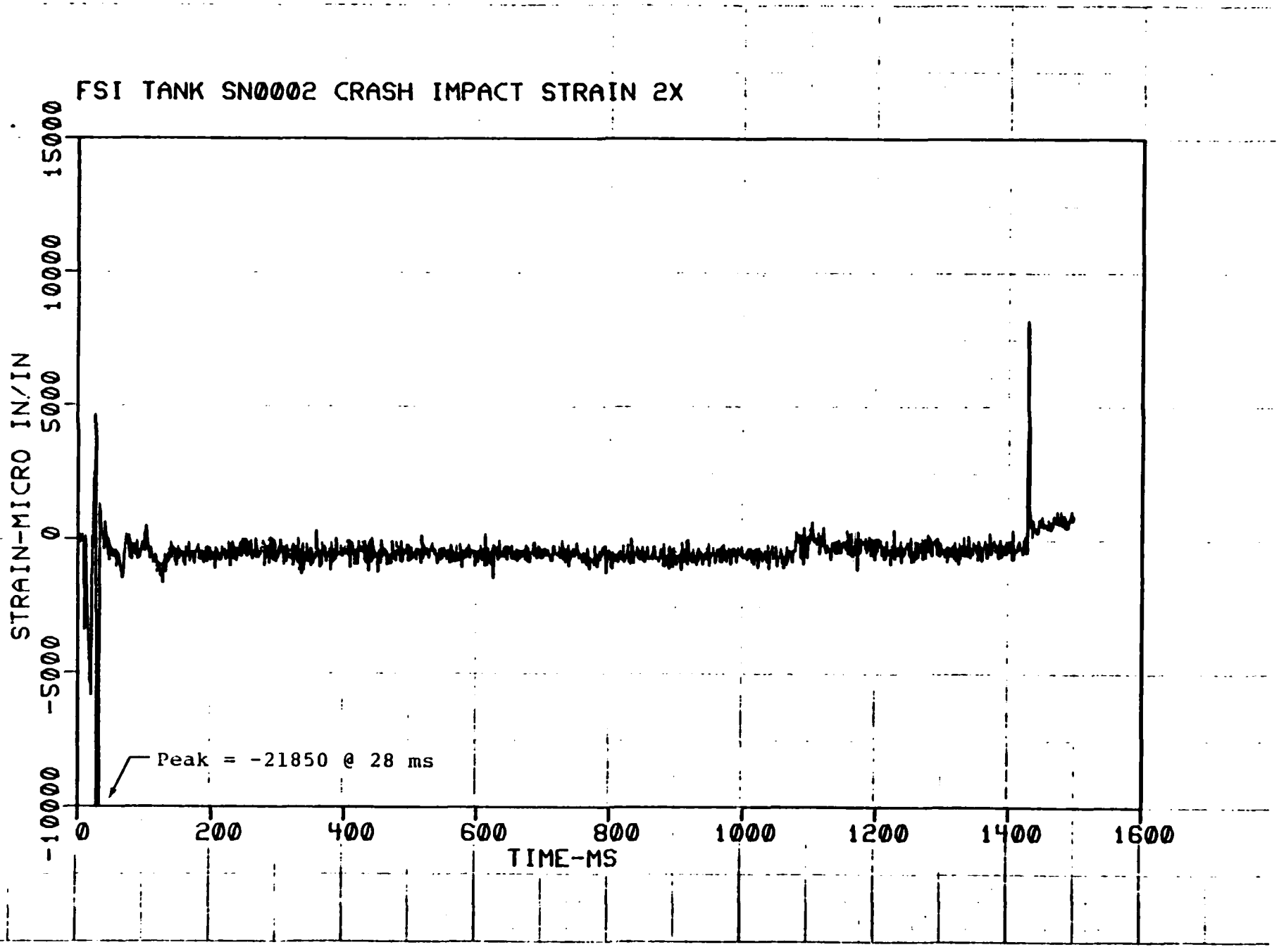

FSI TANK SN0002 CRASH IMPACT PRESSURE 1
PRESSURE-PSIA
-400
0
400
800
1200
1600
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

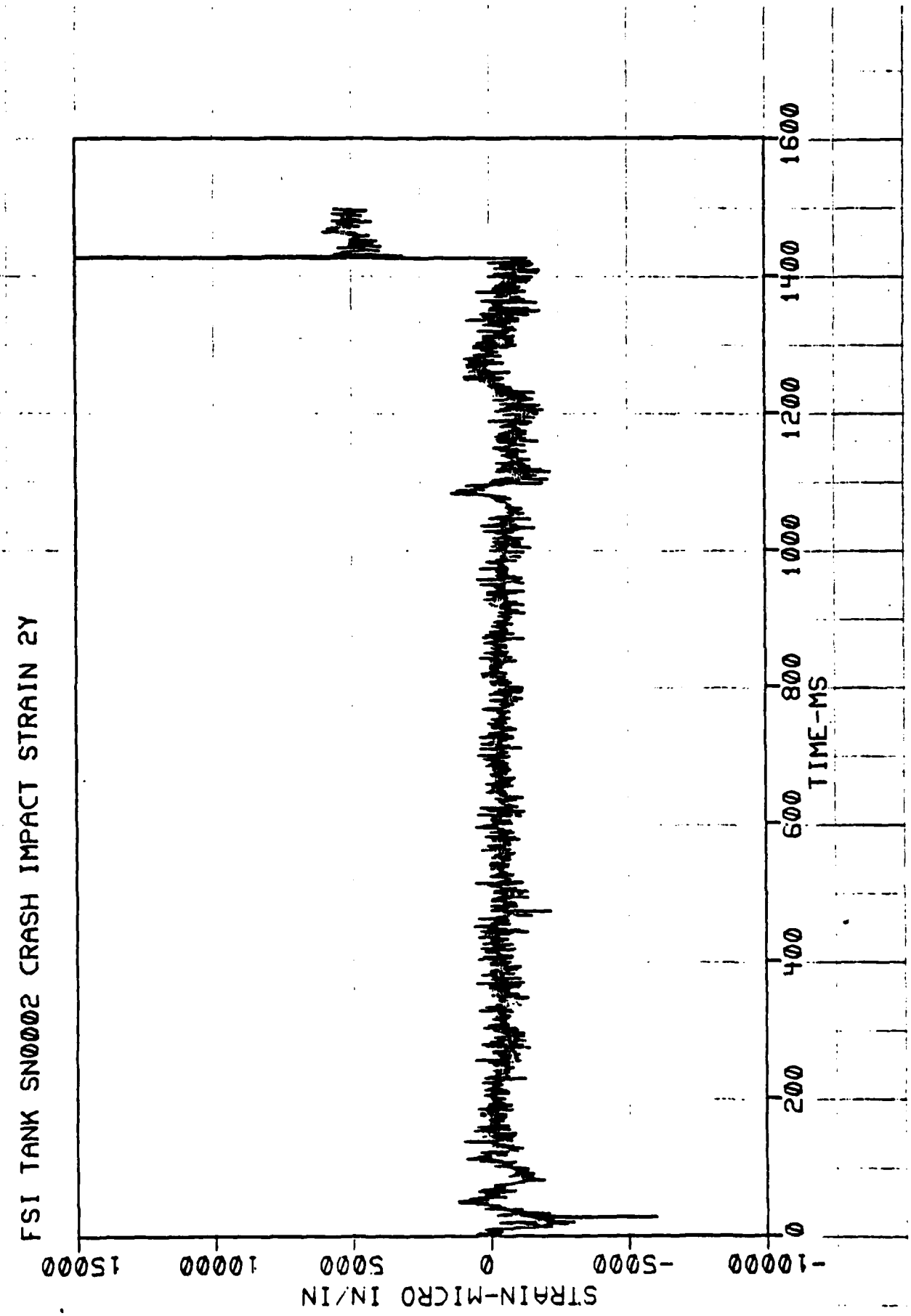

FSI TANK SN0002 CRASH IMPACT PRESSURE 2
PRESSURE-PSIA
50
25
0
-25
-50
-75
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

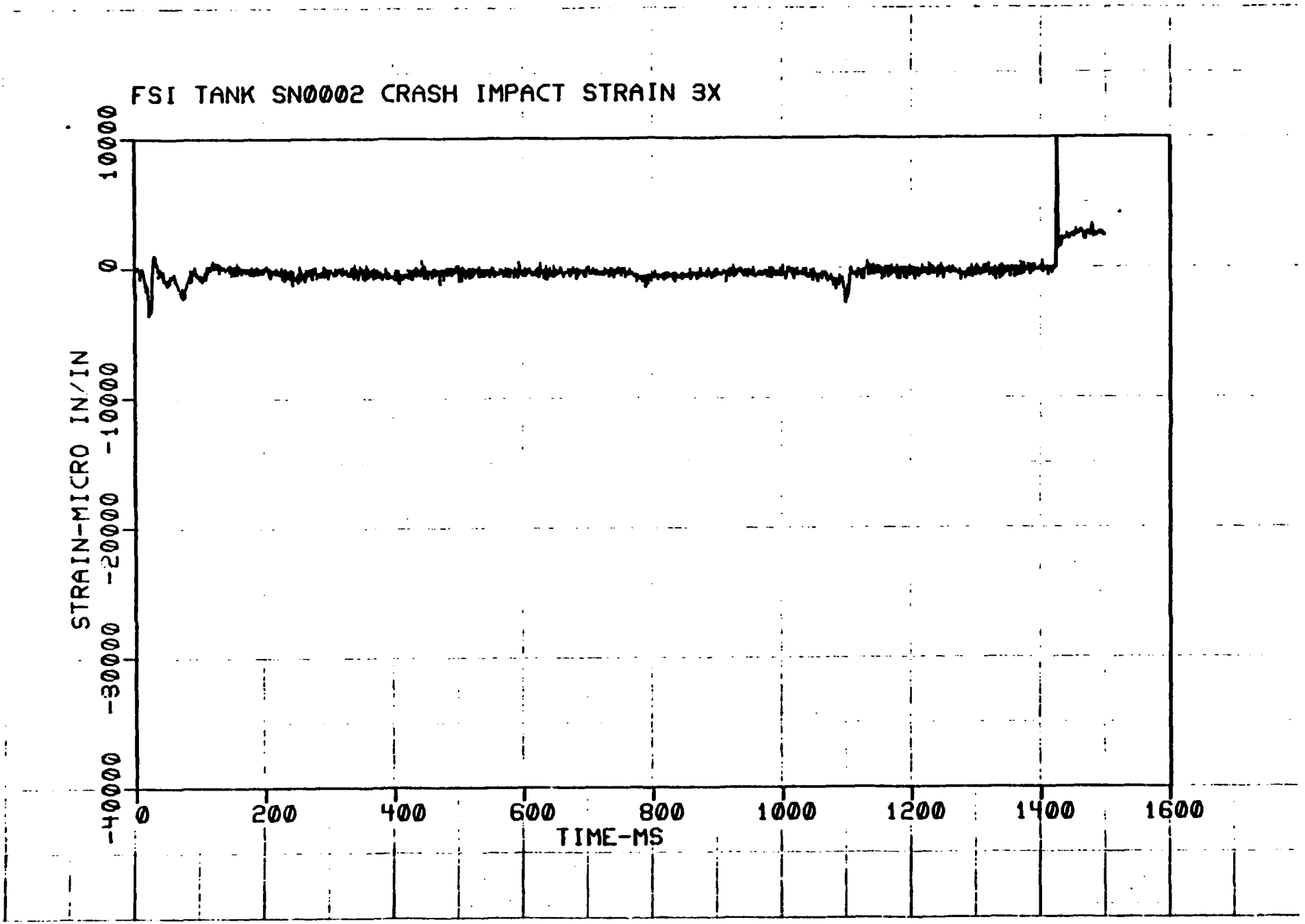

FSI TANK SN0002 CRASH IMPACT PRESSURE 4
PRESSURE-PSIA
1000
750
500
250
0
-250
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

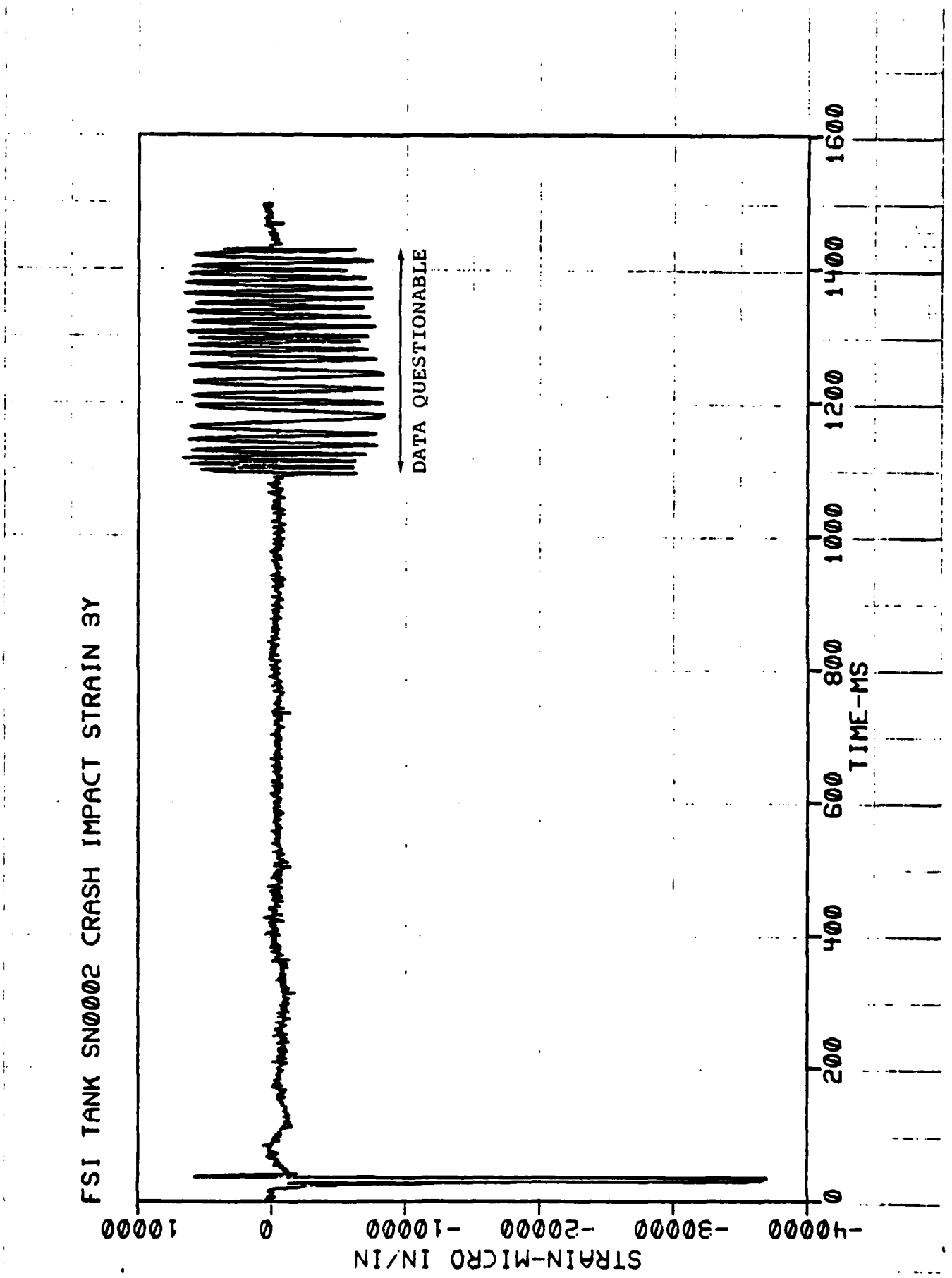

FSI TANK SN0002 CRASH IMPACT STRAIN 1X
SENSOR DESTROYED
STRAIN-MICRO IN/IN
20000
10000
0
-10000
-20000
-30000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

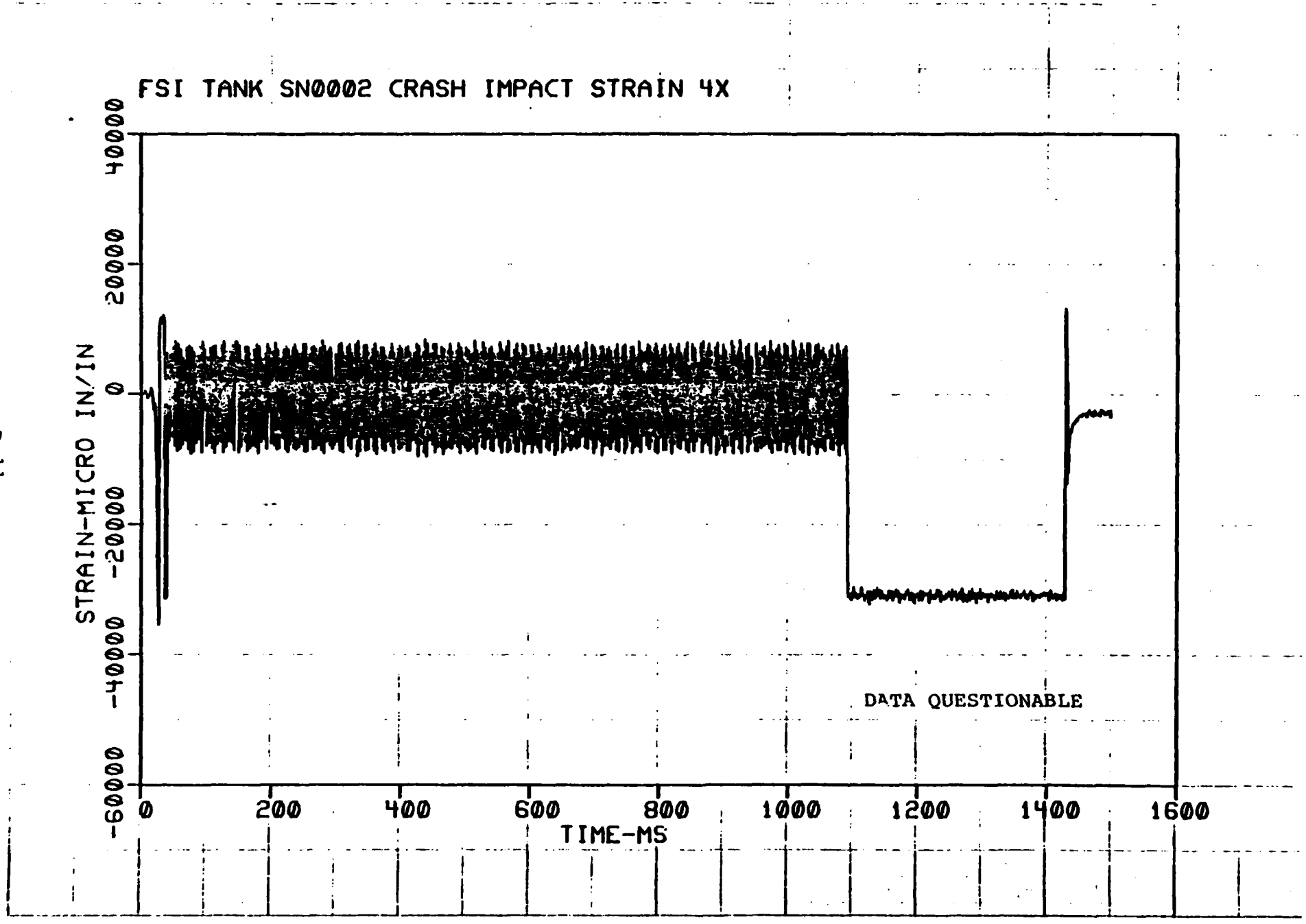

FSI TANK SN0002 CRASH IMPACT STRAIN 1Y
STRAIN-MICRO IN/IN
20000
10000
0
-10000
-20000
-30000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS
SENSOR DESTROYED

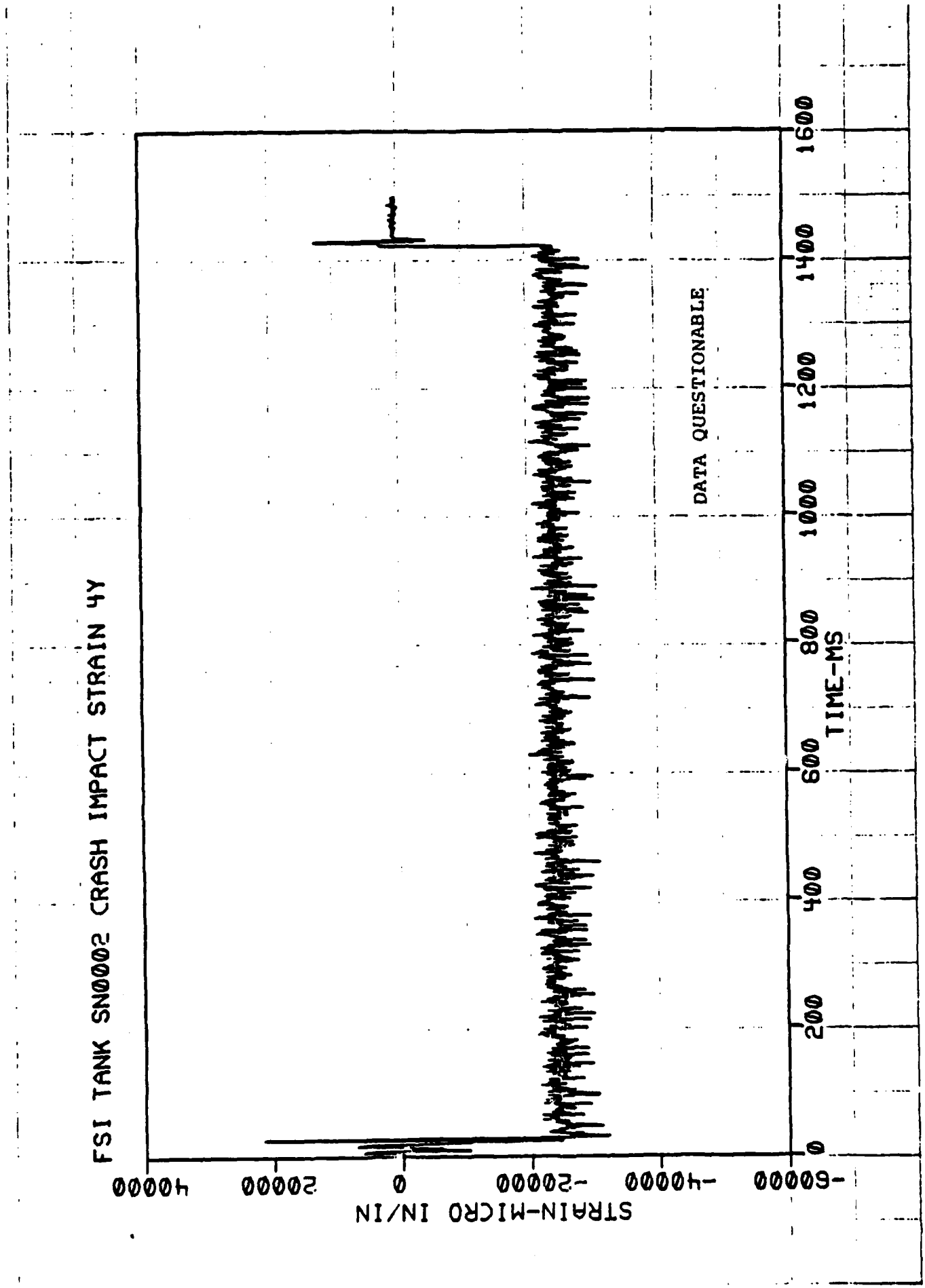

FSI TANK SN0002 CRASH IMPACT STRAIN 2X
STRAIN-MICRO IN/IN
15000
10000
5000
0
-5000
-10000
Peak = -21850 @ 28 ms
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

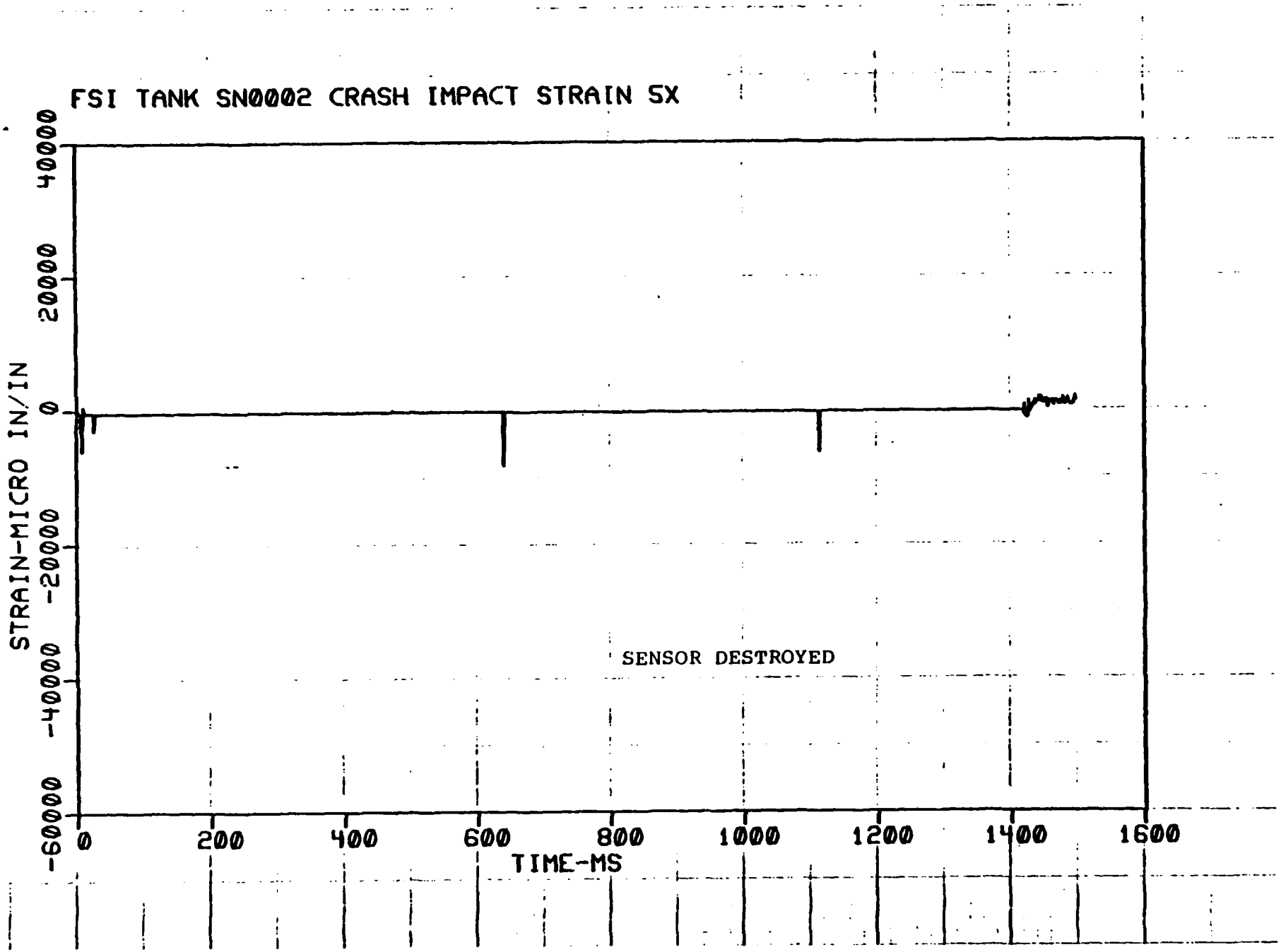

FSI TANK SN0002 CRASH IMPACT STRAIN 2Y
STRAIN-MICRO IN/IN
15000
10000
5000
0
-5000
-10000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

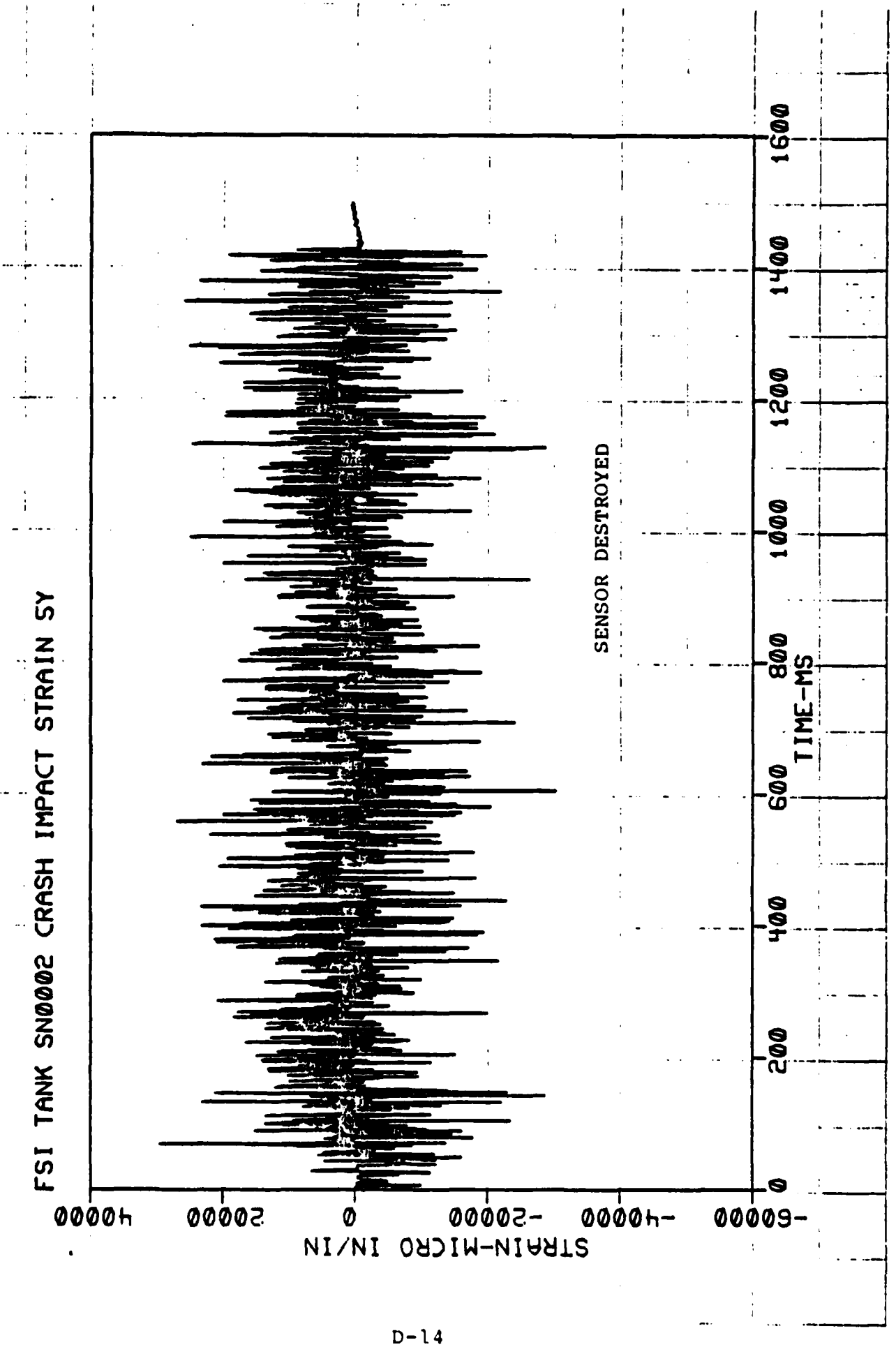

FSI TANK SN0002 CRASH IMPACT STRAIN 3X
STRAIN-MICRO IN/IN
10000
0
-10000
-20000
-30000
-40000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

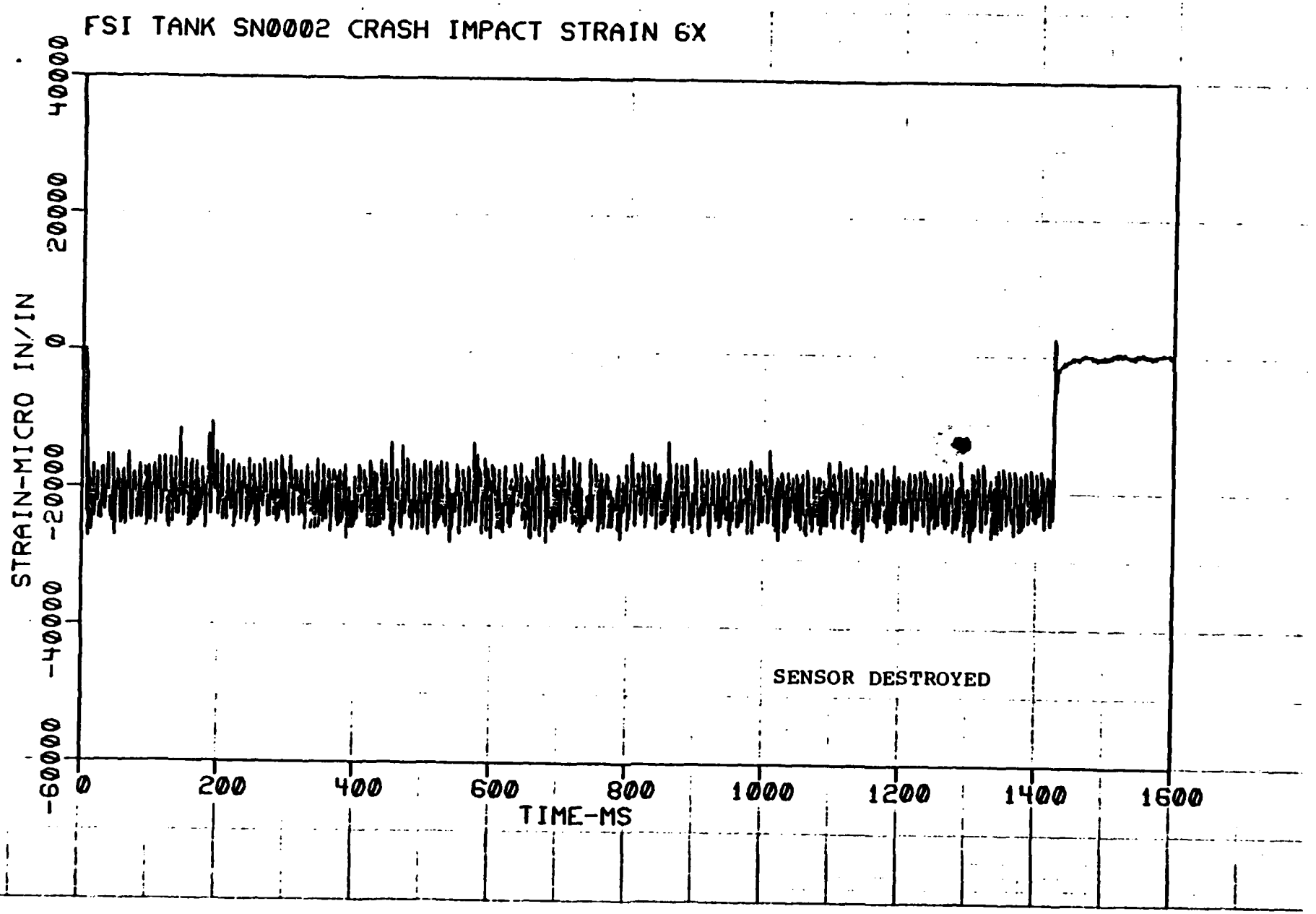

FSI TANK SN0002 CRASH IMPACT STRAIN 3Y
DATA QUESTIONABLE
STRAIN-MICRO IN/IN
10000
0
-10000
-20000
-30000
-40000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

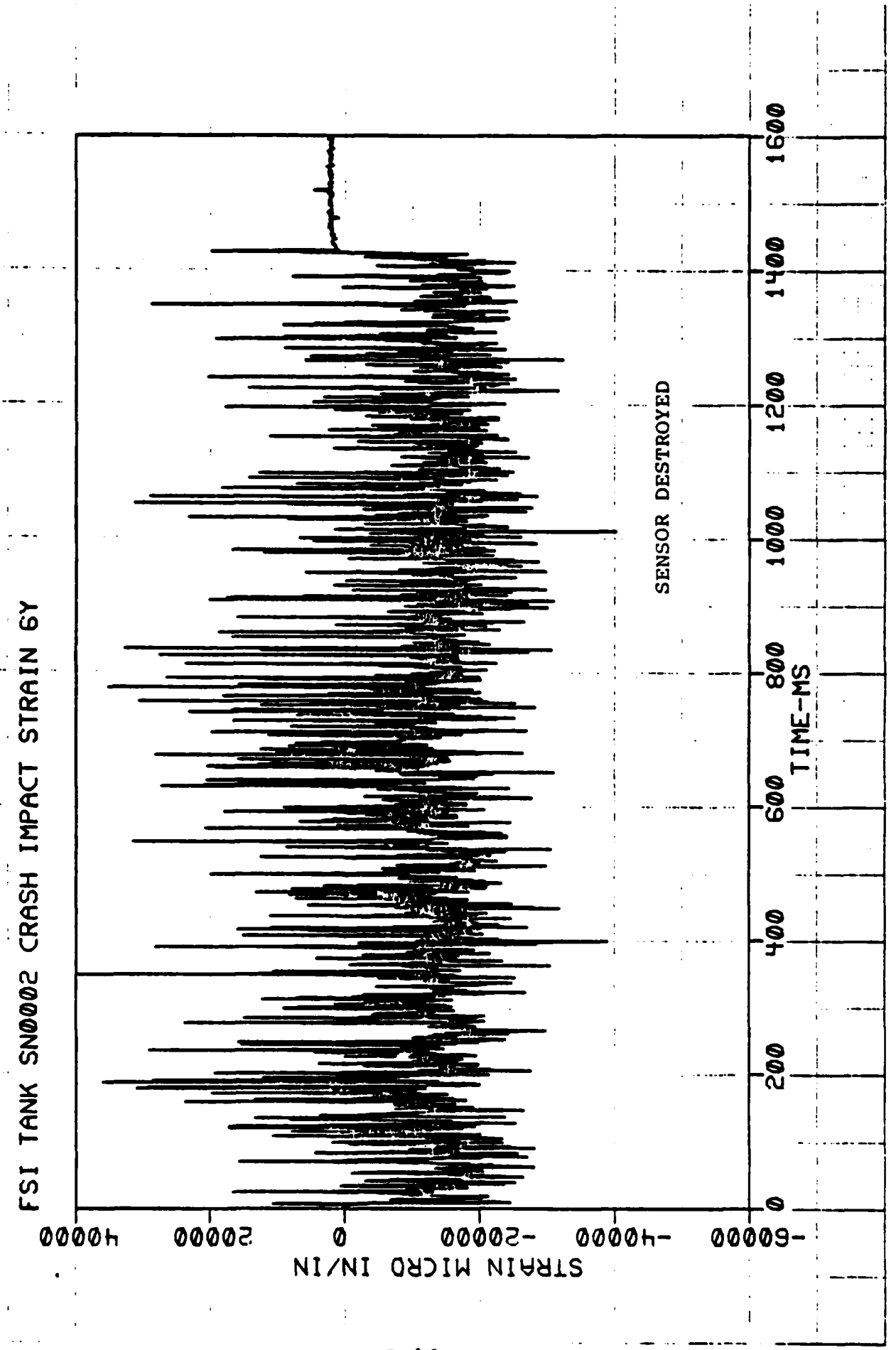

FSI TANK SN0002 CRASH IMPACT STRAIN 4X
STRAIN-MICRO IN/IN
40000
20000
0
-20000
-40000
-60000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS
DATA QUESTIONABLE

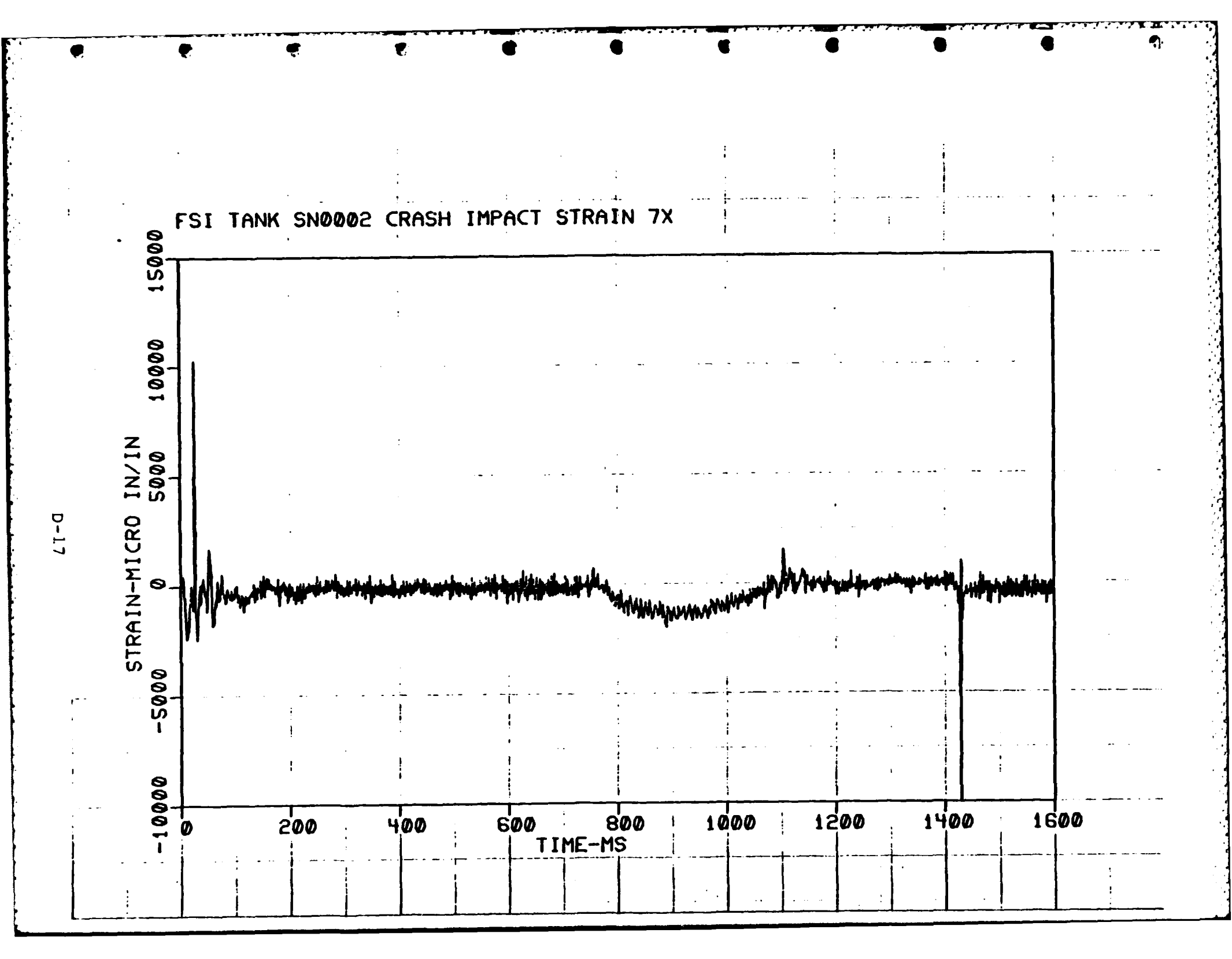

FSI TANK SN0002 CRASH IMPACT STRAIN 4Y
DATA QUESTIONABLE
STRAIN-MICRO IN/IN
40000
20000
0
-20000
-40000
-60000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

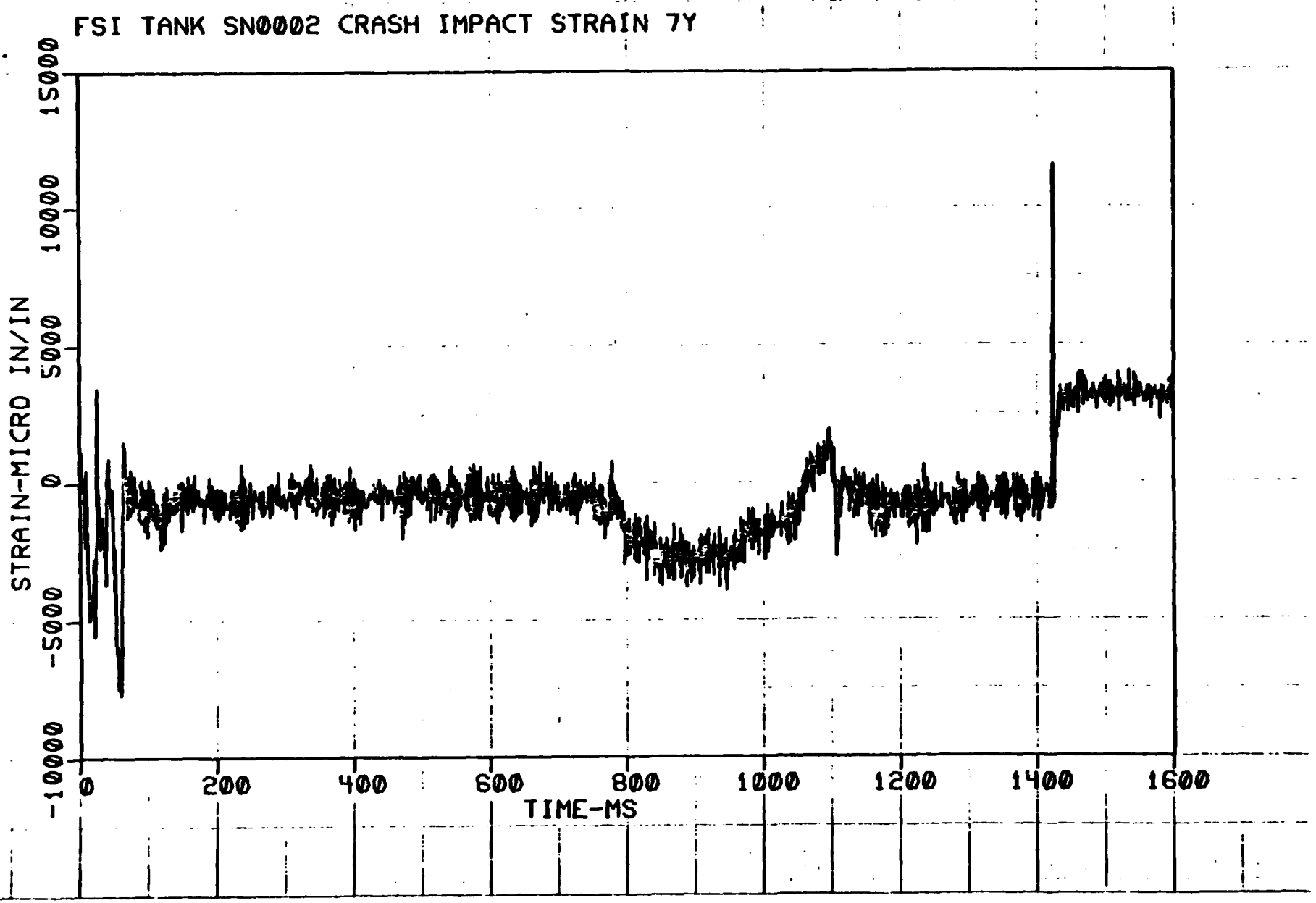

FSI TANK SN0002 CRASH IMPACT STRAIN SX
STRAIN-MICRO IN/IN
40000
20000
0
-20000
-40000
-60000
SENSOR DESTROYED
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

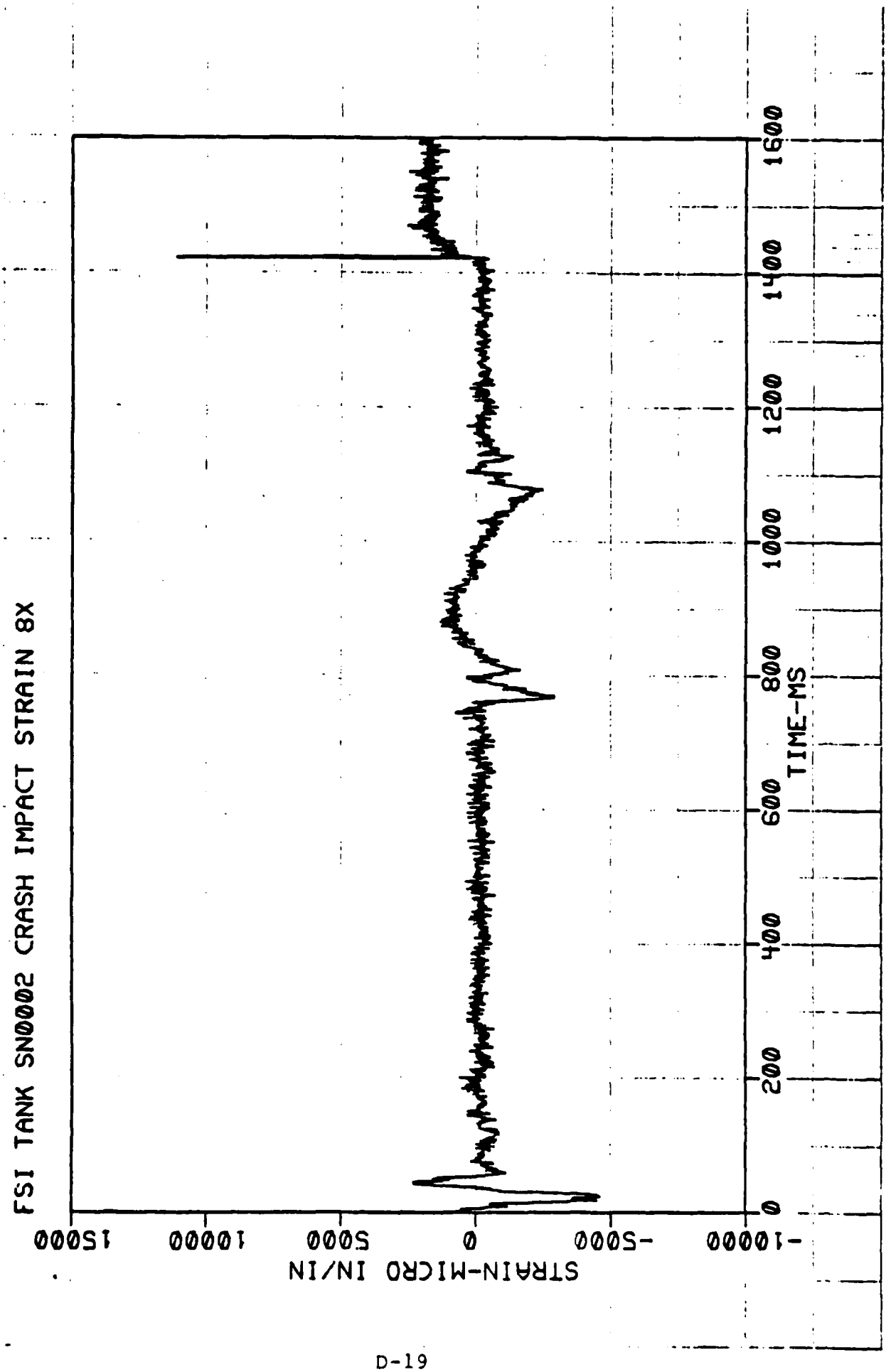

FSI TANK SN0002 CRASH IMPACT STRAIN SY
SENSOR DESTROYED
STRAIN-MICRO IN/IN
40000
20000
0
-20000
-40000
-60000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

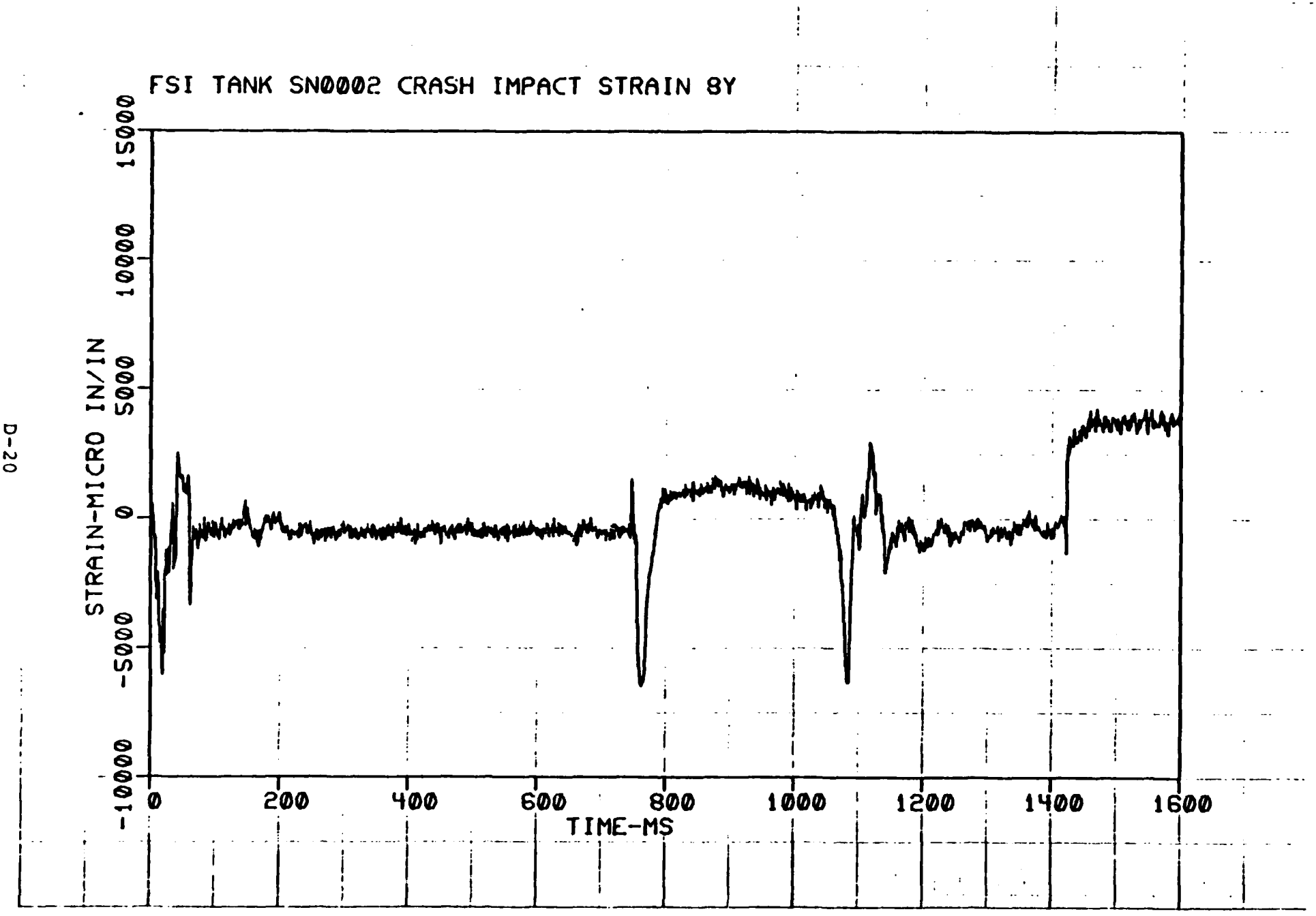

FSI TANK SN0002 CRASH IMPACT STRAIN 6X
STRAIN-MICRO IN/IN
40000
20000
0
-20000
-40000
-60000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS
SENSOR DESTROYED

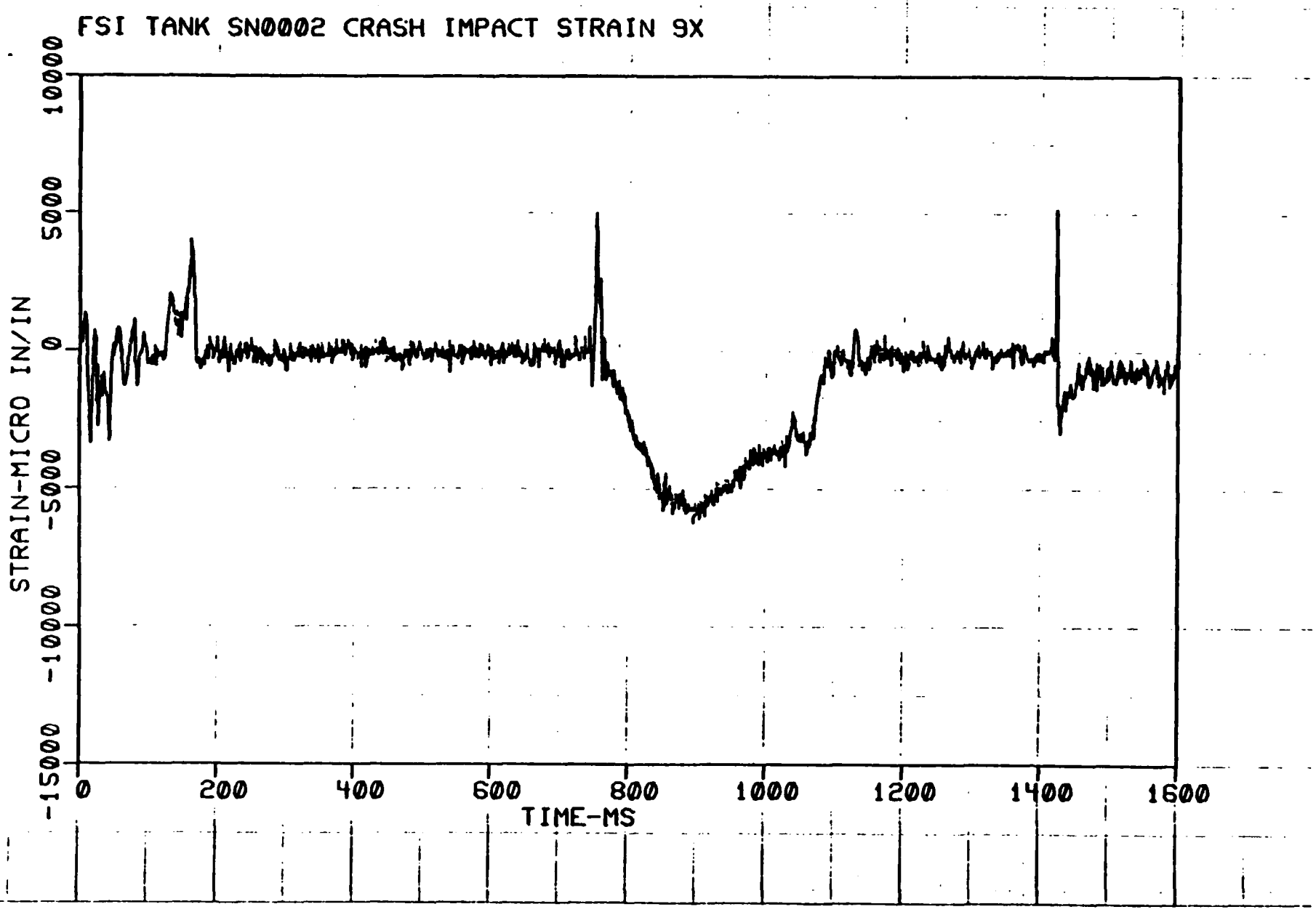

FSI TANK SN0002 CRASH IMPACT STRAIN 6Y
STRAIN MICRO IN/IN
40000
20000
0
-20000
-40000
-60000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600
SENSOR DESTROYED

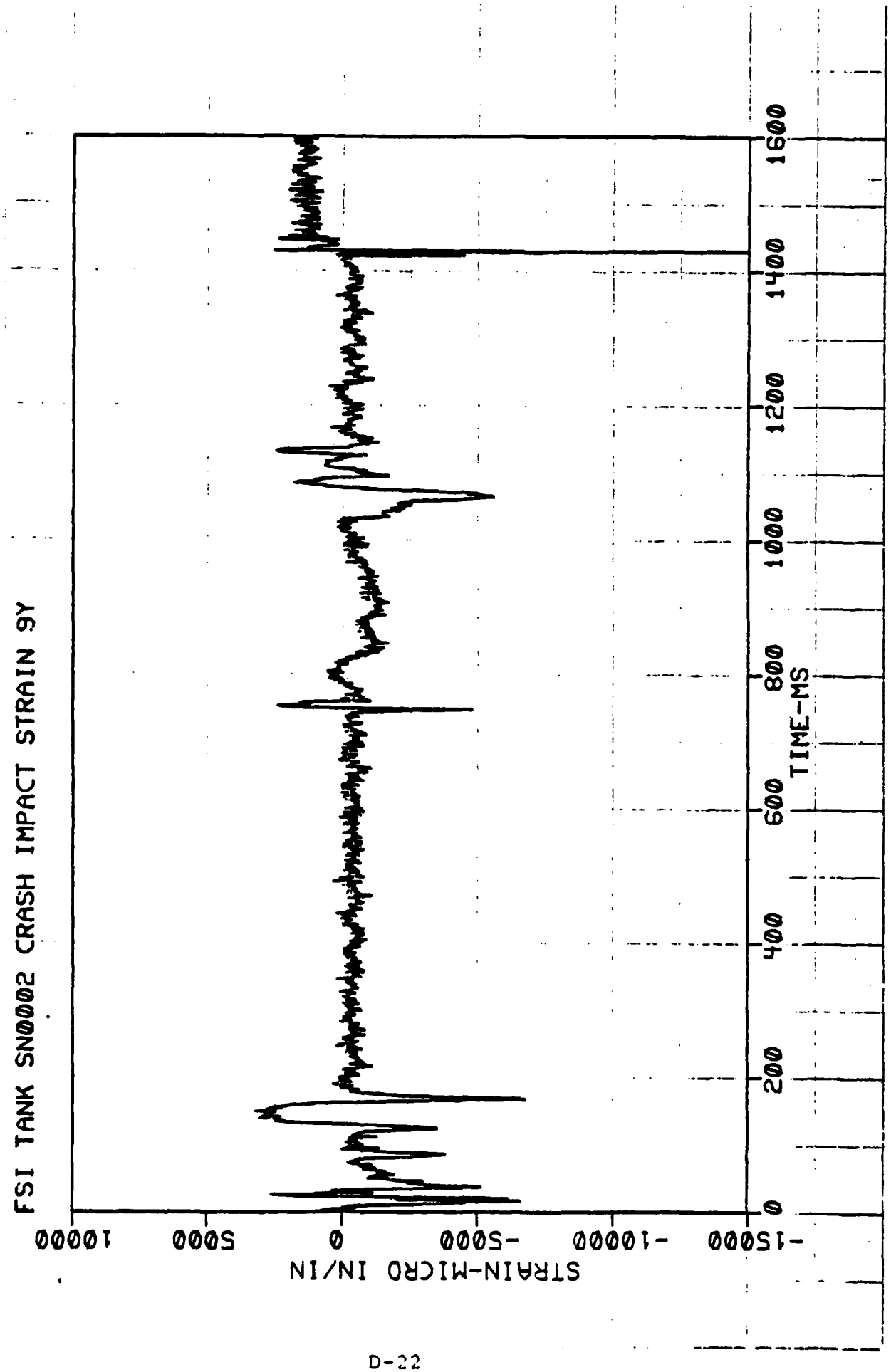

FSI TANK SN0002 CRASH IMPACT STRAIN 7X
STRAIN-MICRO IN/IN
15000
10000
5000
0
-5000
-10000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

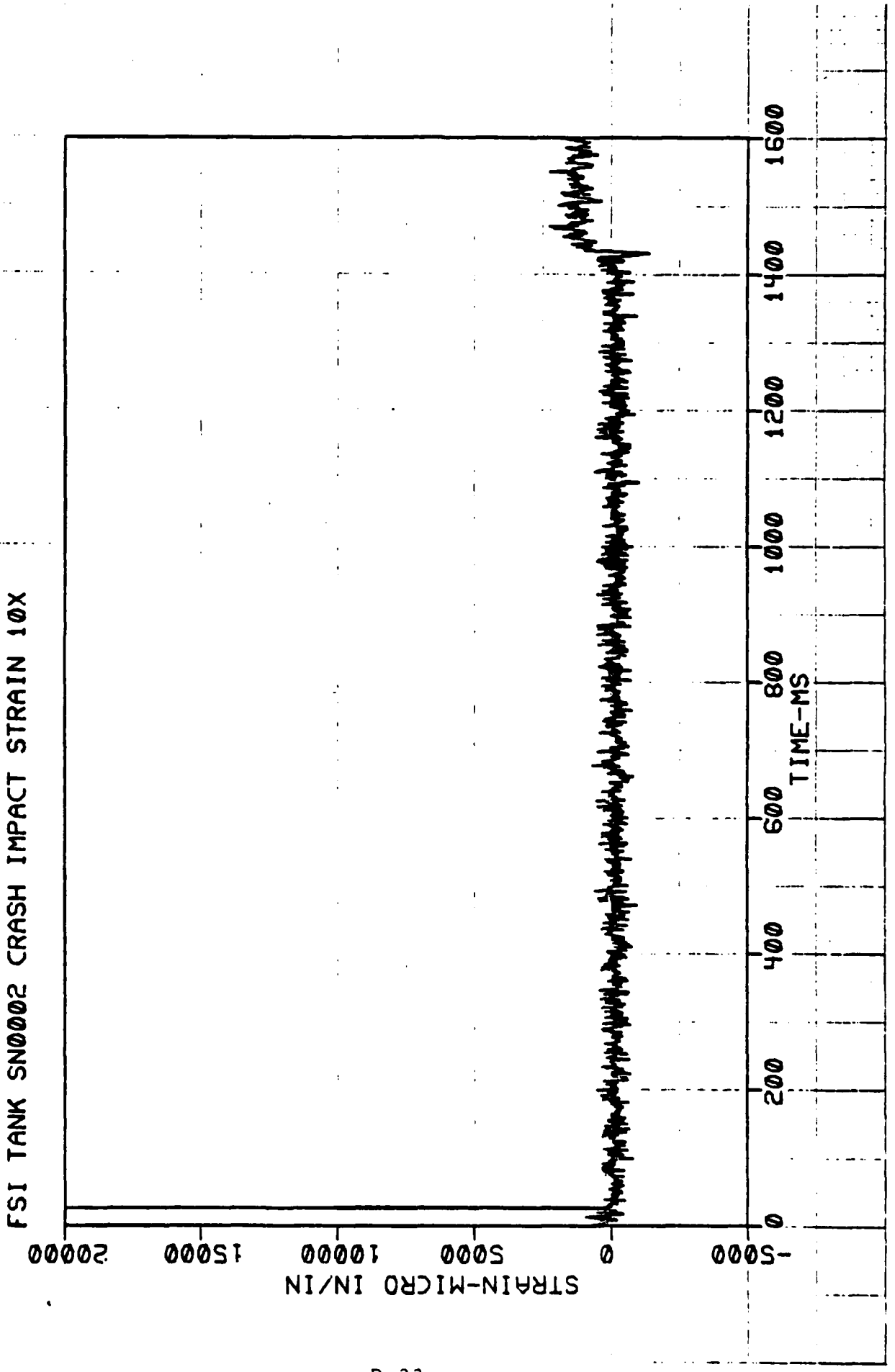

FSI TANK SN0002 CRASH IMPACT STRAIN 7Y
STRAIN-MICRO IN/IN
15000
10000
5000
0
-5000
-10000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

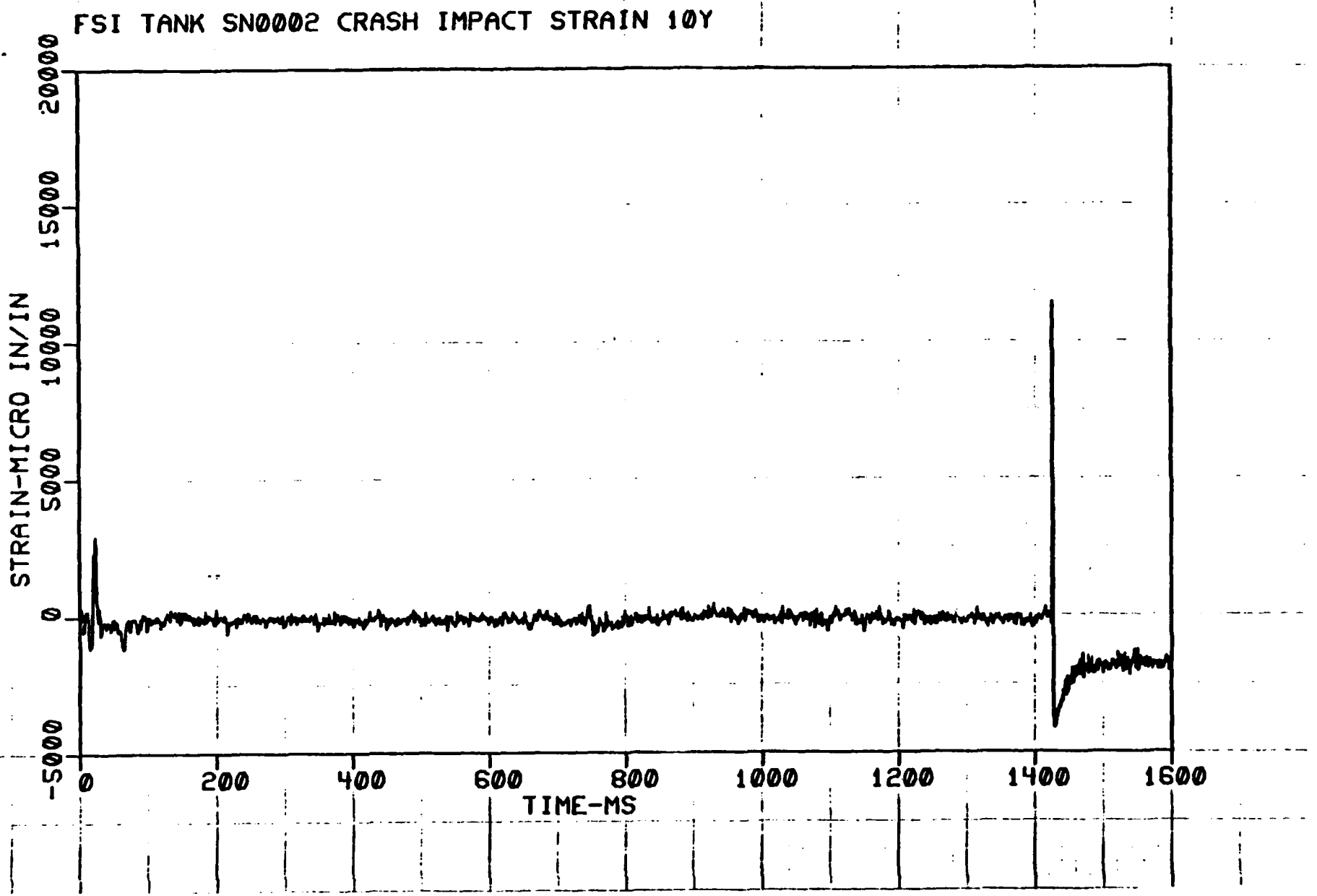

FSI TANK SN0002 CRASH IMPACT STRAIN 8X
STRAIN-MICRO IN/IN
15000
10000
5000
0
-5000
-10000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

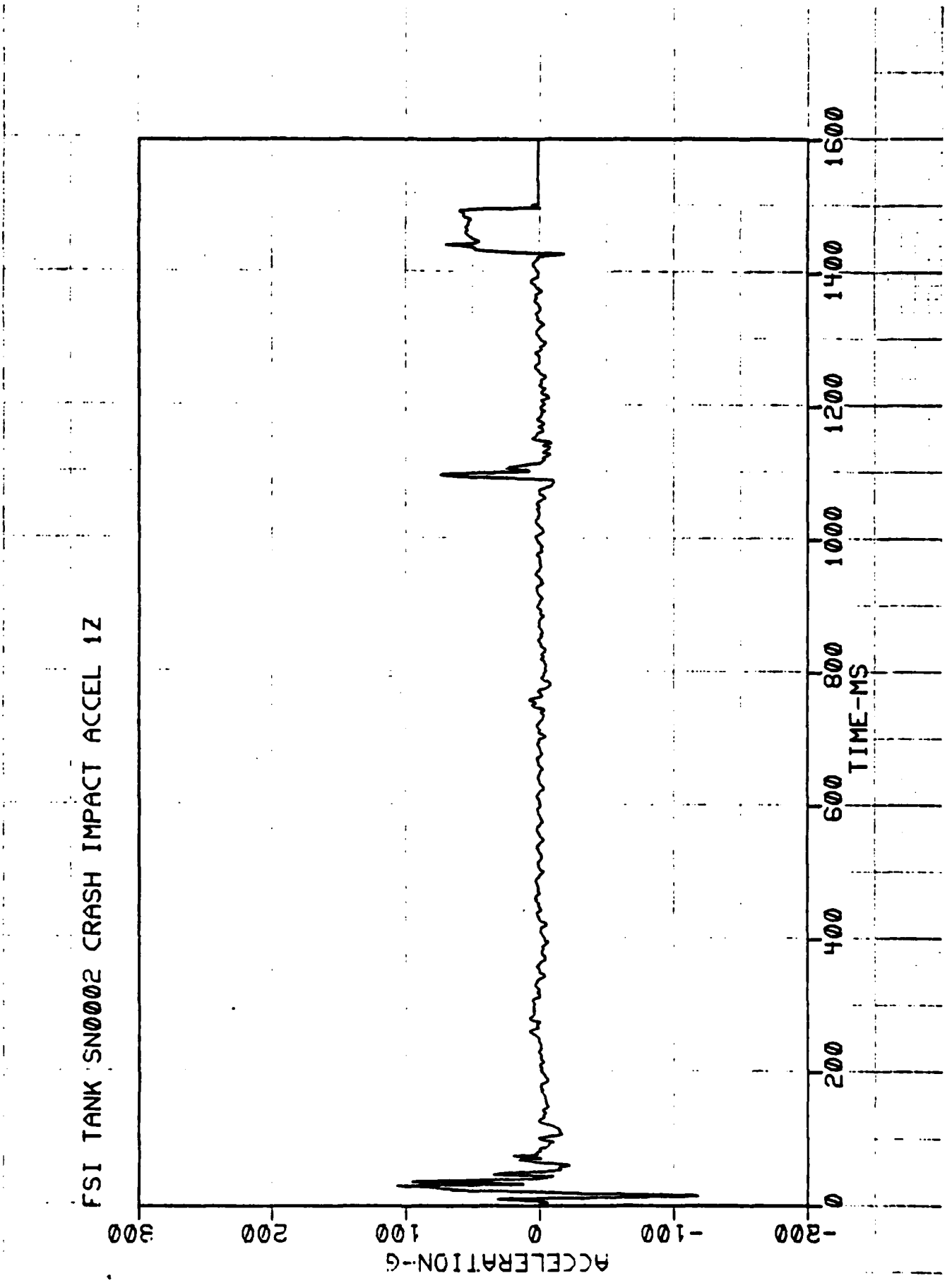

FSI TANK SN0002 CRASH IMPACT STRAIN 8Y
STRAIN-MICRO IN/IN
15000
10000
5000
0
-5000
-10000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

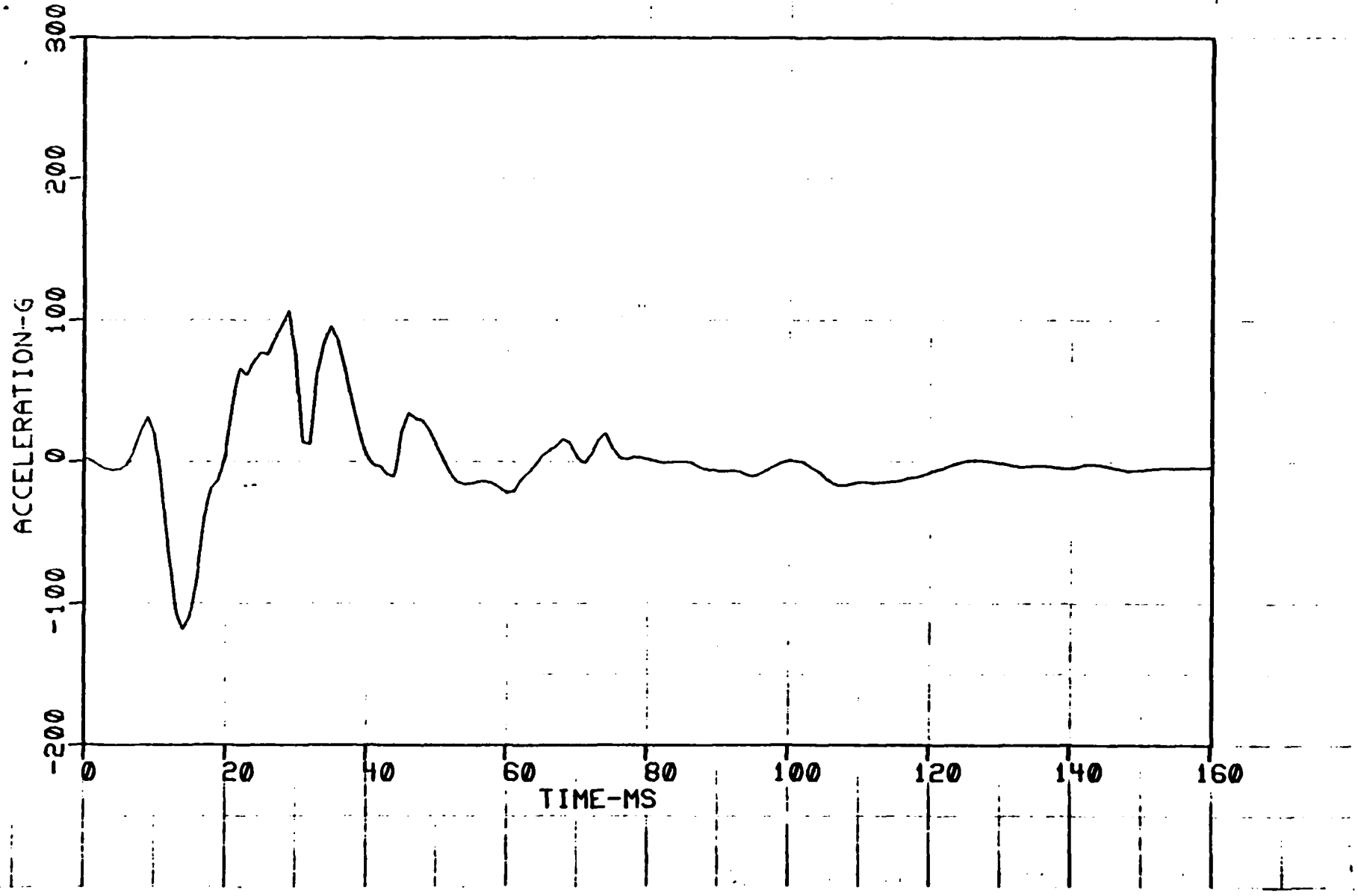

FSI TANK SN0002 CRASH IMPACT STRAIN 9X
STRAIN-MICRO IN/IN
10000
5000
0
-5000
-10000
-15000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS

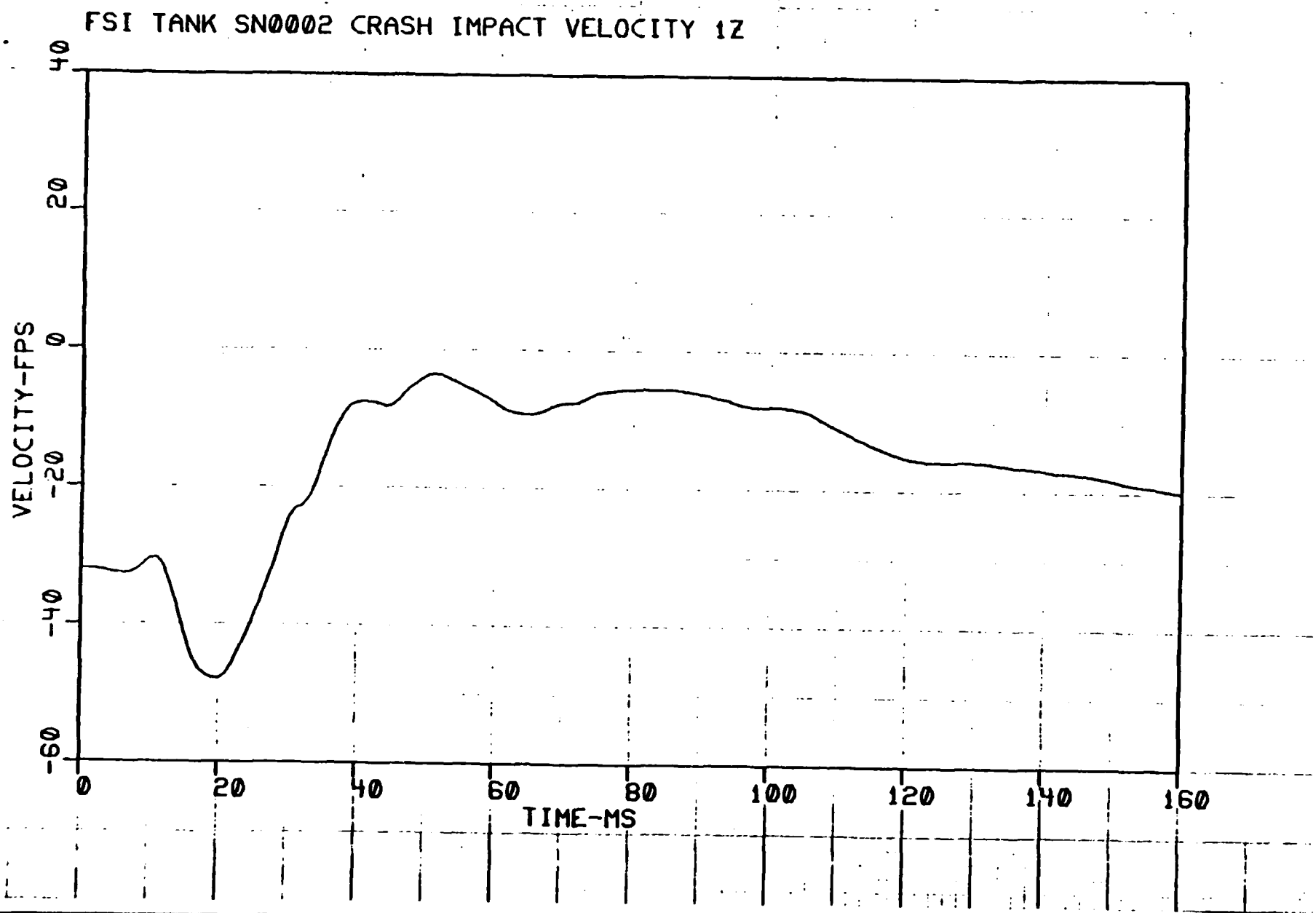

FSI TANK SN0002 CRASH IMPACT STRAIN 9Y
STRAIN-MICRO IN/IN
10000
5000
0
-5000
-10000
-15000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600

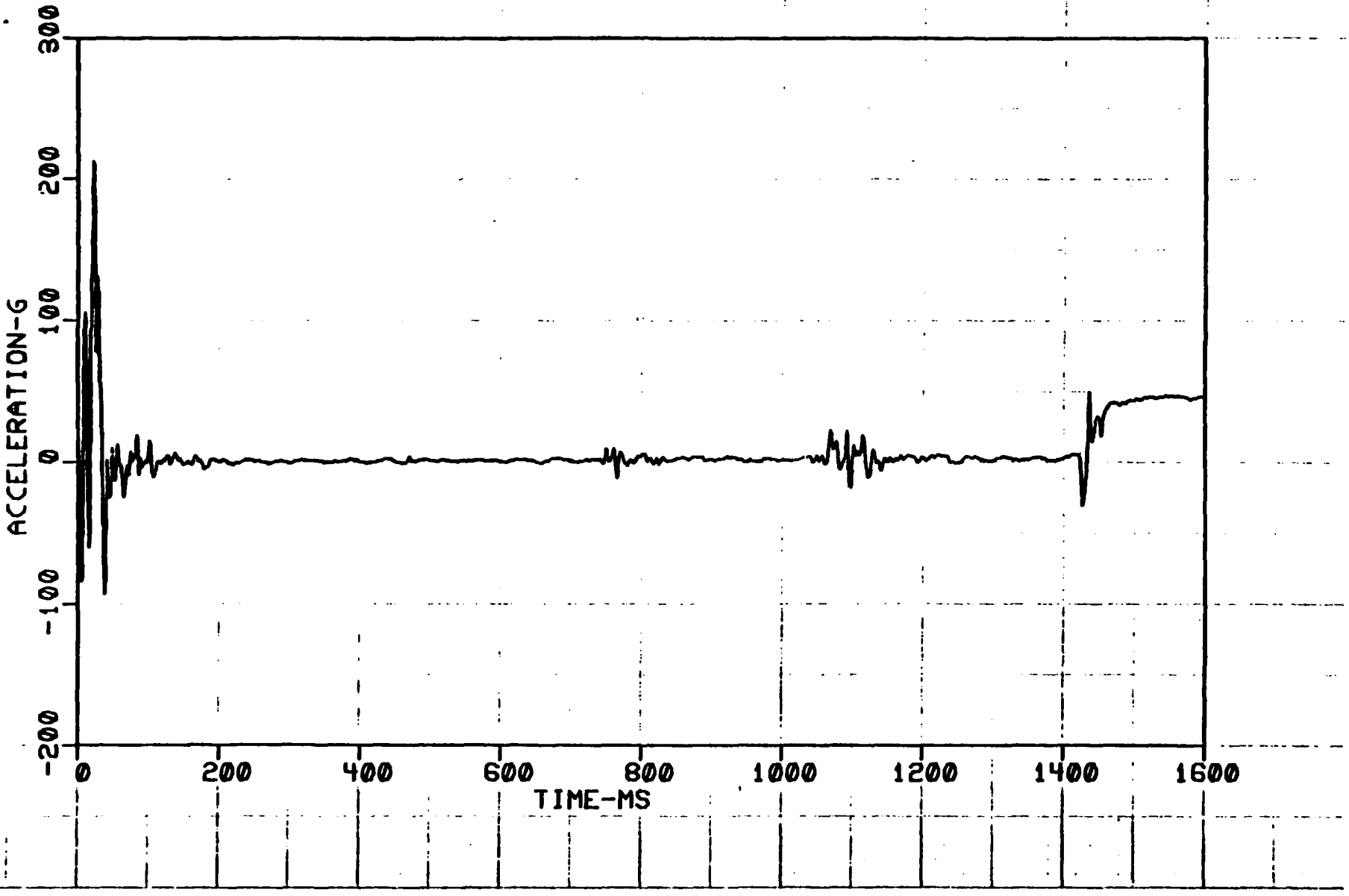

FSI TANK SN0002 CRASH IMPACT STRAIN 10X
STRAIN-MICRO IN/IN
-5000
0
5000
10000
15000
20000
TIME-MS
0
200
400
600
800
1000
1200
1400
1600


FSI TANK SN0002 CRASH IMPACT STRAIN 10Y
STRAIN-MICRO IN/IN
20000
15000
10000
5000
0
-5000
0
200
400
600
800
1000
1200
1400
1600
TIME-MS


FSI TANK SN0002 CRASH IMPACT ACCEL 1Z
ACCELERATION-G
300
200
100
0
-100
-200
0
200
400
600
800
1000
1200
1400
1600
TIME-MS


FSI TANK SN0002 CRASH IMPACT ACCEL 1Z
ACCELERATION-G
300
200
100
0
-100
-200
0
20
40
60
80
100
120
140
160
TIME-MS


FSI TANK SN0002 CRASH IMPACT VELOCITY 1Z
VELOCITY-FPS
40
20
0
-20
-40
-60
0
20
40
60
80
100
120
140
160
TIME-MS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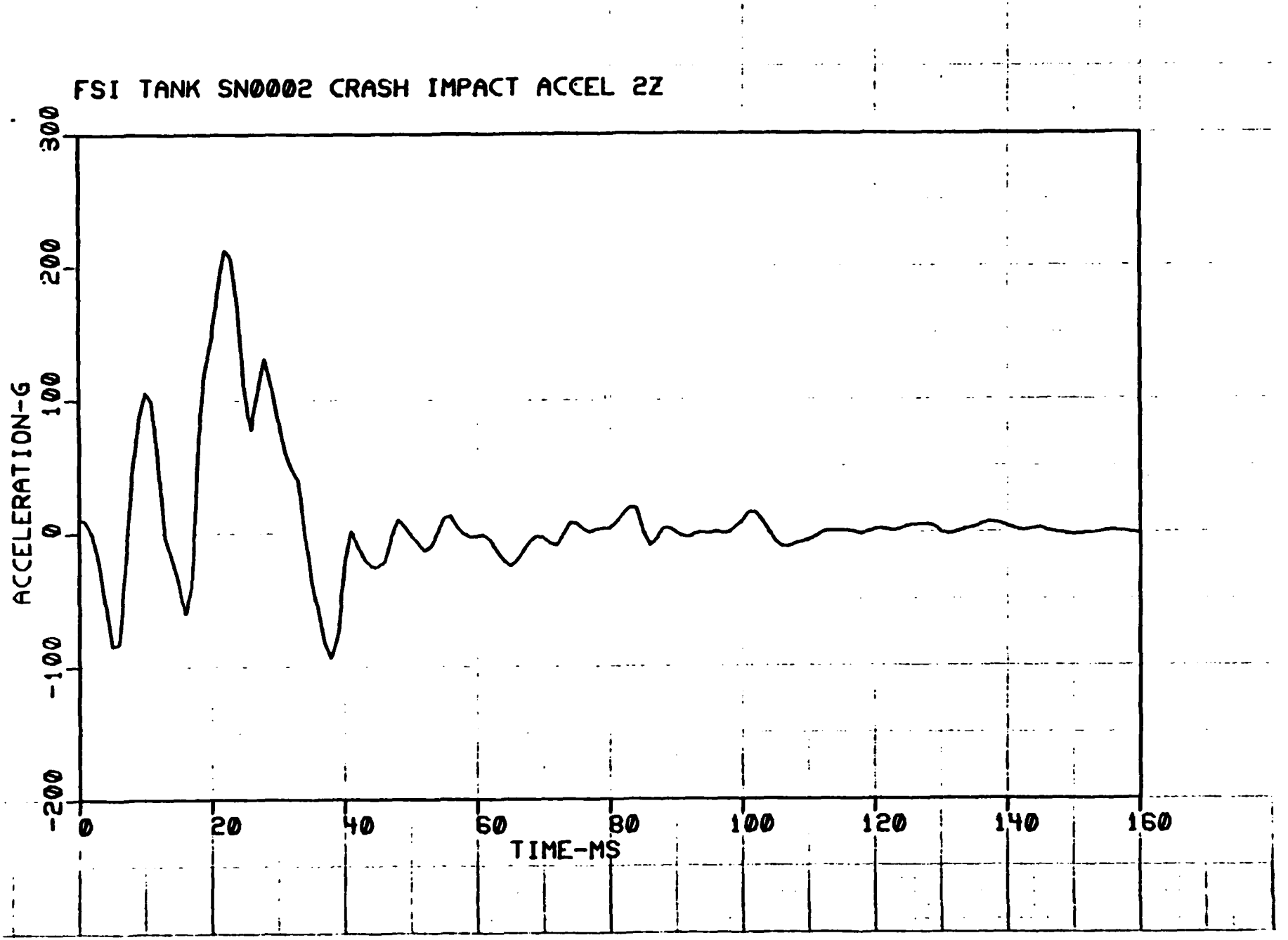
1400
1600
TIME-MS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ACCELERATION-G
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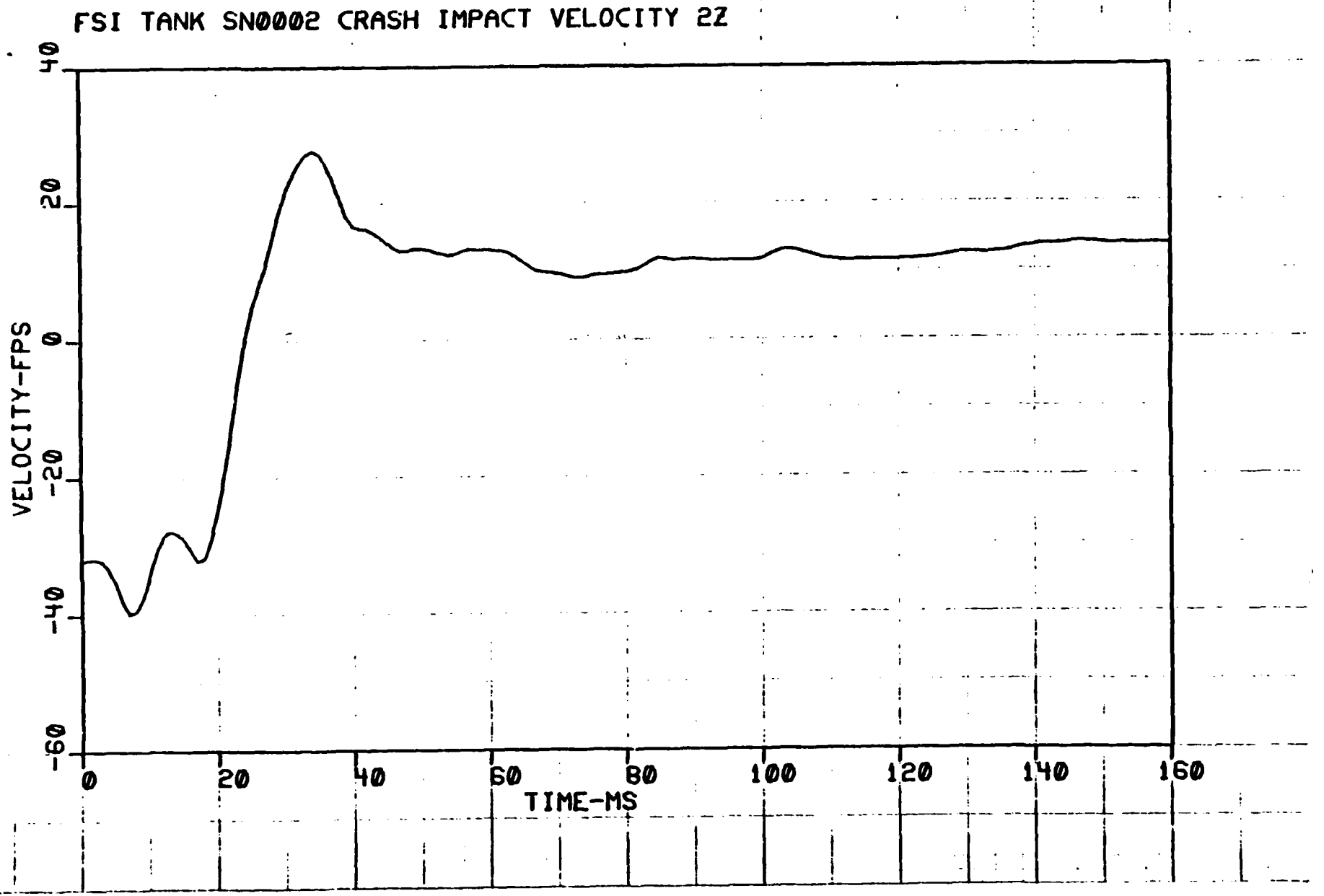
200
100
0
-100
-200
0
20
40
60
80
100
120
140
160
TIME-MS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VELOCITY-FPS
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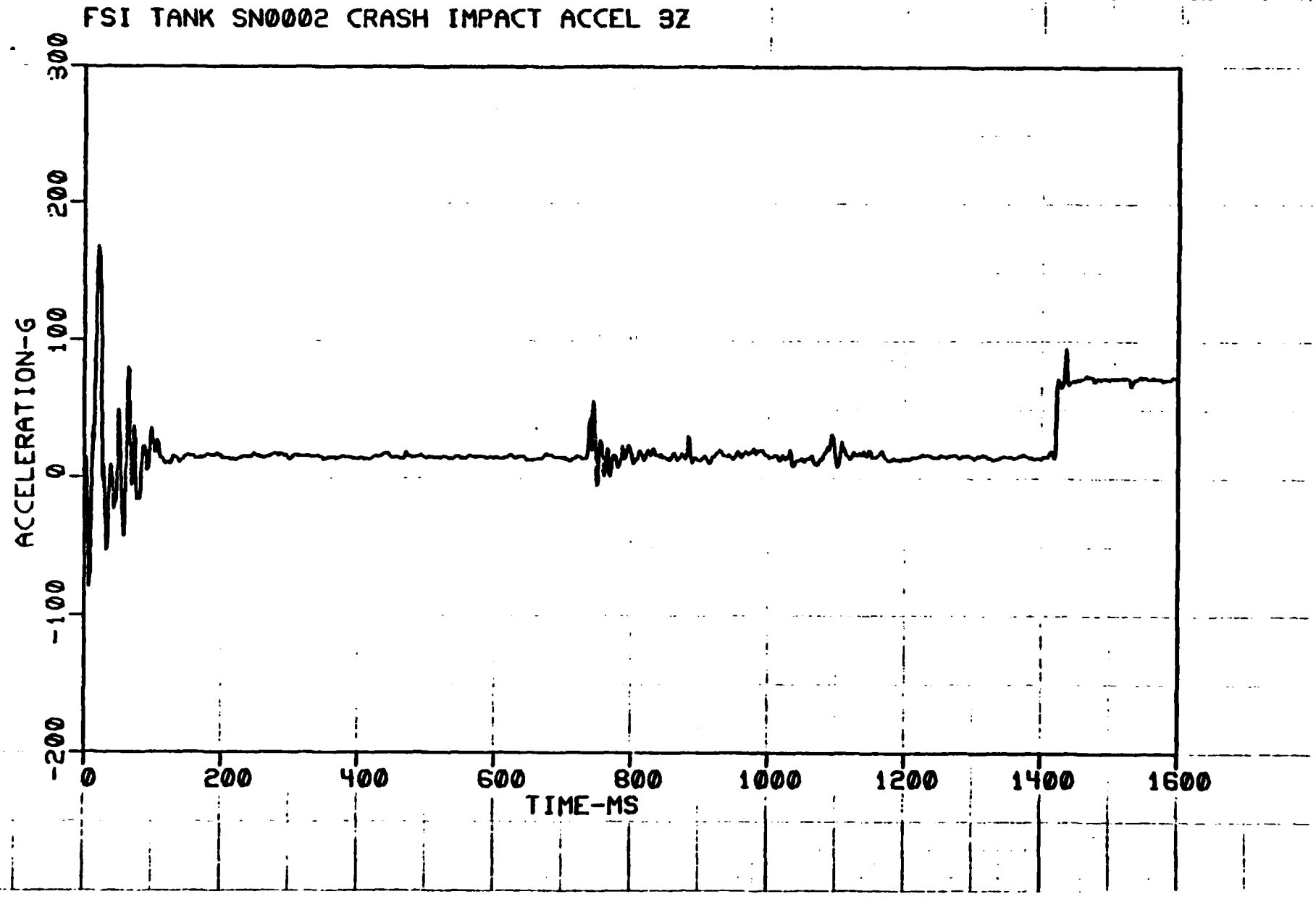
20
0
-20
-40
-60
0
20
40
60
80
100
120
140
160
TIME-MS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ACCELERATION-G
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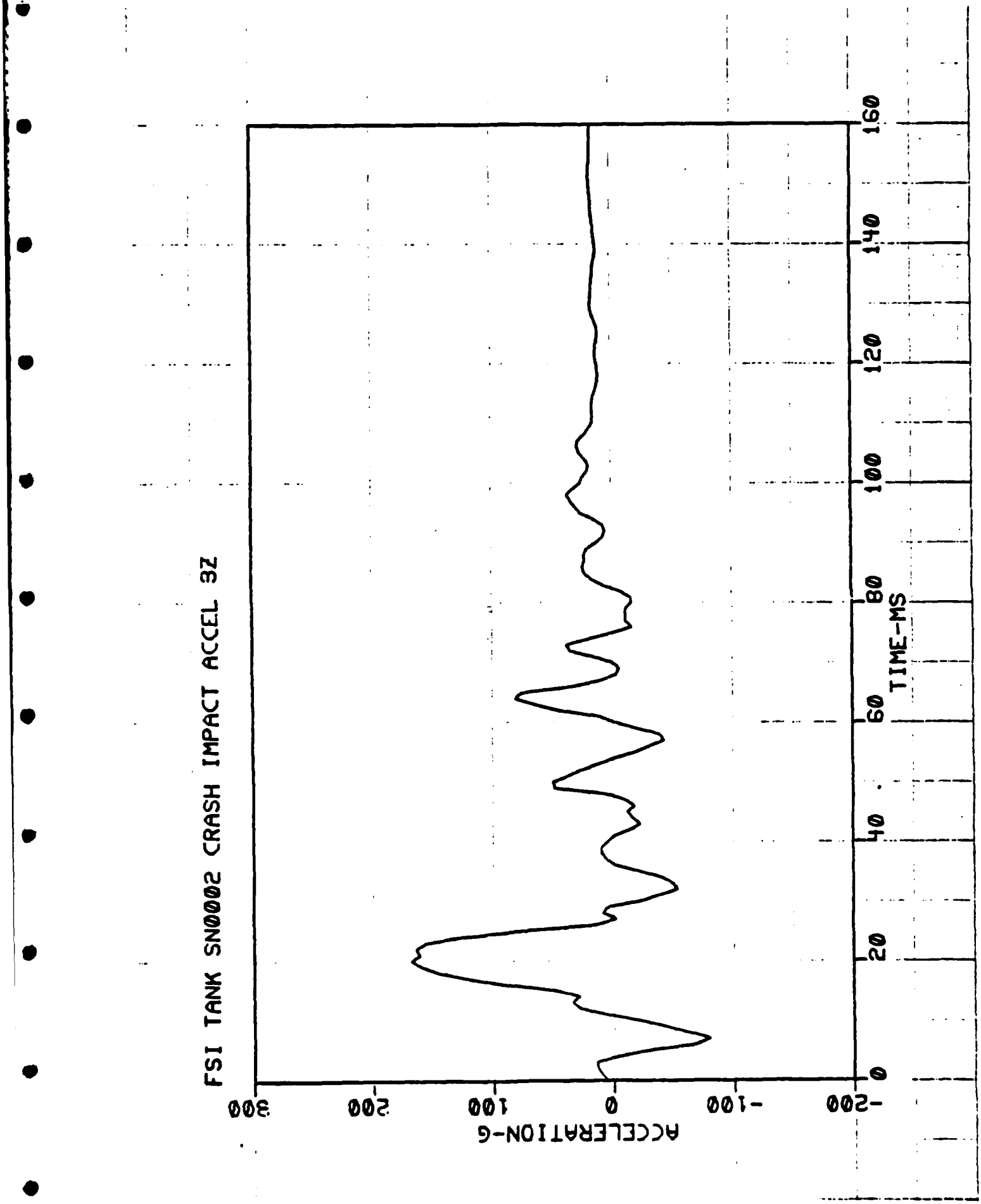
-100
-200
0
200
400
600
800
1000
1200
1400
1600
TIME-MS


FSI TANK SN0002 CRASH IMPACT ACCEL 3Z
ACCELERATION-G
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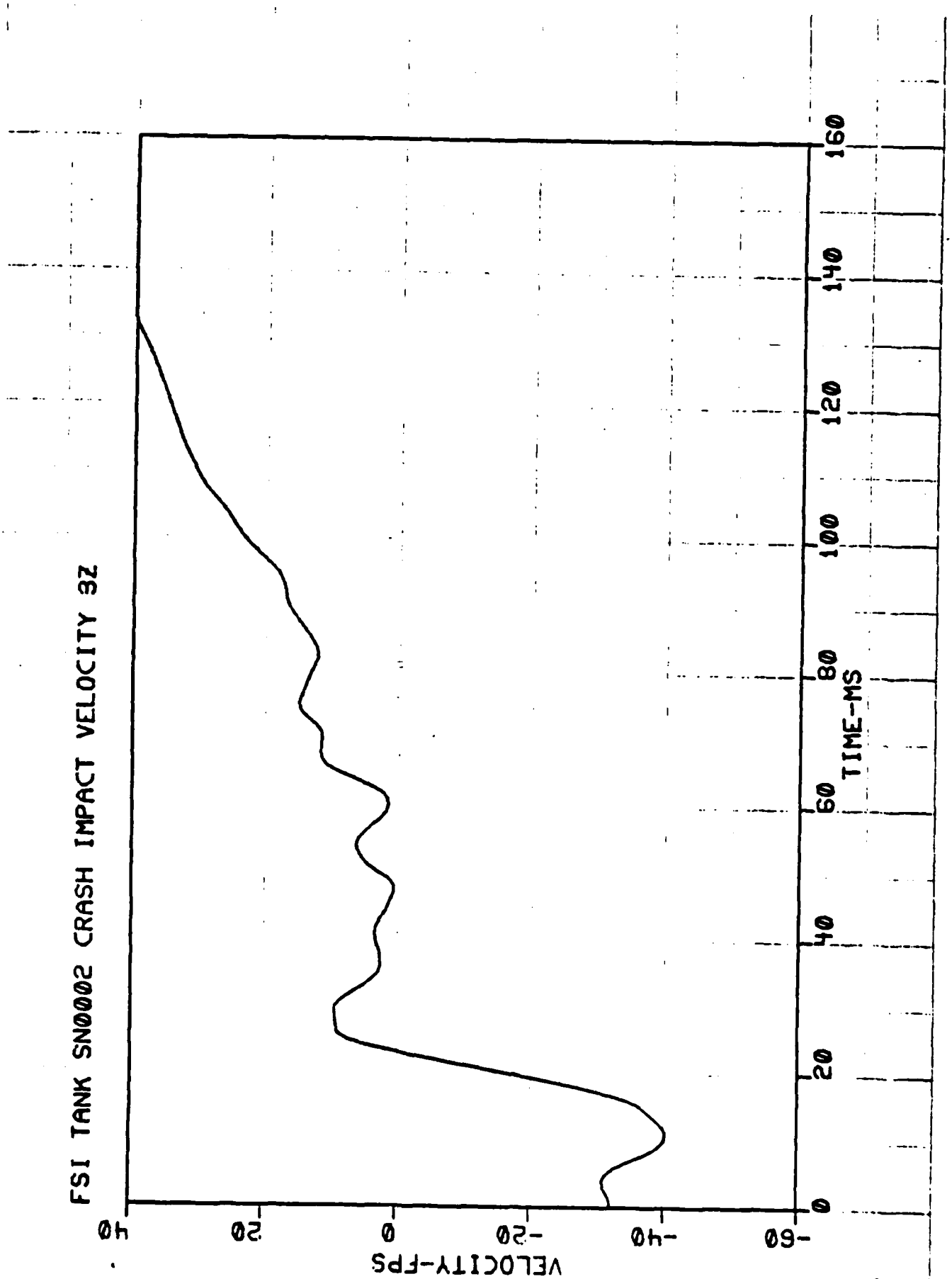
-100
0
100
200
300
TIME-MS
0
20
40
60
80
100
120
140
160


FSI TANK SN0002 CRASH IMPACT VELOCITY 3Z
VELOCITY-FPS
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20
0
-20
-40
-60
TIME-MS
0
20
40
60
80
100
120
140
160

APPENDIX E

Fiber Science, Inc.

Document Number
QTP-2191 Section "S"

QUALIFICATION TEST PROCEDURE
H-53 TANK
REQUIREMENTS FOR CRASH IMPACT TEST

DOCUMENT NUMBER

QTP-2191 SECTION "S"

TITLE

QUALIFICATION TEST PROCEDURE

H-53 TANK

REQUIREMENTS FOR CRASH IMPACT TEST

REVISIONS

LTR.	DATE	PREPARED	APPROVED	DESCRIPTION

PREPARED BY: Richard Lyman DATE: 11/20/80

CHECKED BY: Randy Stone DATE: 12/5/80

APPROVED BY: C. A. Patunka Jr. DATE: 12/6/80

FIBER SCIENCE, INC.
SALT LAKE CITY, UTAH

NO. QTP-2191 Section "S"

1.0 SCOPE

This procedure covers the requirements for crash impact testing of the 450 Gallon Filament Wound External Fuel Tank for the H-53 helicopter.

2.0 APPLICABLE DOCUMENTS

2.1 MILITARY SPECIFICATIONS

MIL-STD-831	Test Reports, Preparation of.

2.2 TECHNICAL EXHIBIT

ASD/ENFEA-78	Tank - 450 gallon external fuel, filament wound lightweight explosion proof.

2.3 DRAWINGS

FIBER SCIENCE

2191-001	Tank - Installation, 450 gallon H-53

SARGENT FLETCHER

27-450-4400	Pylon Assembly - 450 gallon fuel tank.

3.0 REQUIREMENTS

3.1 TEST ARTICLES

Two tank assemblies (2191-001) fueled to a full tank condition and mounted to a pylon (27-450-4400) which in turn is mounted to a portable rig shall be subjected to the impact of an aerial drop as described in Technical Exhibit ASD/ENFEA-78. Paragraph 3.4.1.7.5.

3.2 TEST ARRANGEMENT

The test arrangement shall be similar to that shown in Concept A or B of Figure 1 with all reasonable precautions taken to simulate the actual mounting of the tank and pylon to the helicopter. Other concepts of dropping the tank may be recommended but must be approved before use.

3.3 TEST METHOD

The tanks shall be filled to the normal full position with water and suspended in a 2^{o} nose down position by the pylon support points and secured to the portable test fixture. The tank shall then be dropped for ground impact testing with a forward impact velocity of 39.2 ± 2 feet per second (45 ± 2 feet per second with fuel) and a vertical velocity of 35.3 ± 2 feet per second (40 ± 2 feet per second with fuel), see Figure 2. The impact angle of the tank with respect to the ground shall be between 0^{o} and 15^{o} nose up. Refer to Figure 2. Total allowable leakage is .25 gallons per minute maximum for this test.

3.4 TEST INSTRUMENTATION

High speed full color movies shall be taken with a 16 mm. camera capable of photographing 1000 frames per second minimum at the time of impact. Pressure in the tank during the time interval of the impact transient shall be measured and recorded at four points as shown in Figure 3. Ten (10) biaxial strain gauges, as shown in Figure 3, shall also be attached to record tank structural loading during the test. Twelve (12) color still photos shall be taken of the impact damaged areas and any other highly stressed or failed areas after the test.

3.4.1 INSTRUMENTATION CALIBRATION

All instrumentation shall be calibrated and capable of reading or recording data within ± 2% of its full scale value. No instrument shall be used that has not been calibrated within the previous calibration period.

3.5 TEST PROCEDURES

The test procedures shall be in accordance with paragraph 4 of this document.

3.6 DOCUMENTATION

At the conclusion of testing a test report will be prepared for submission to the contractor.

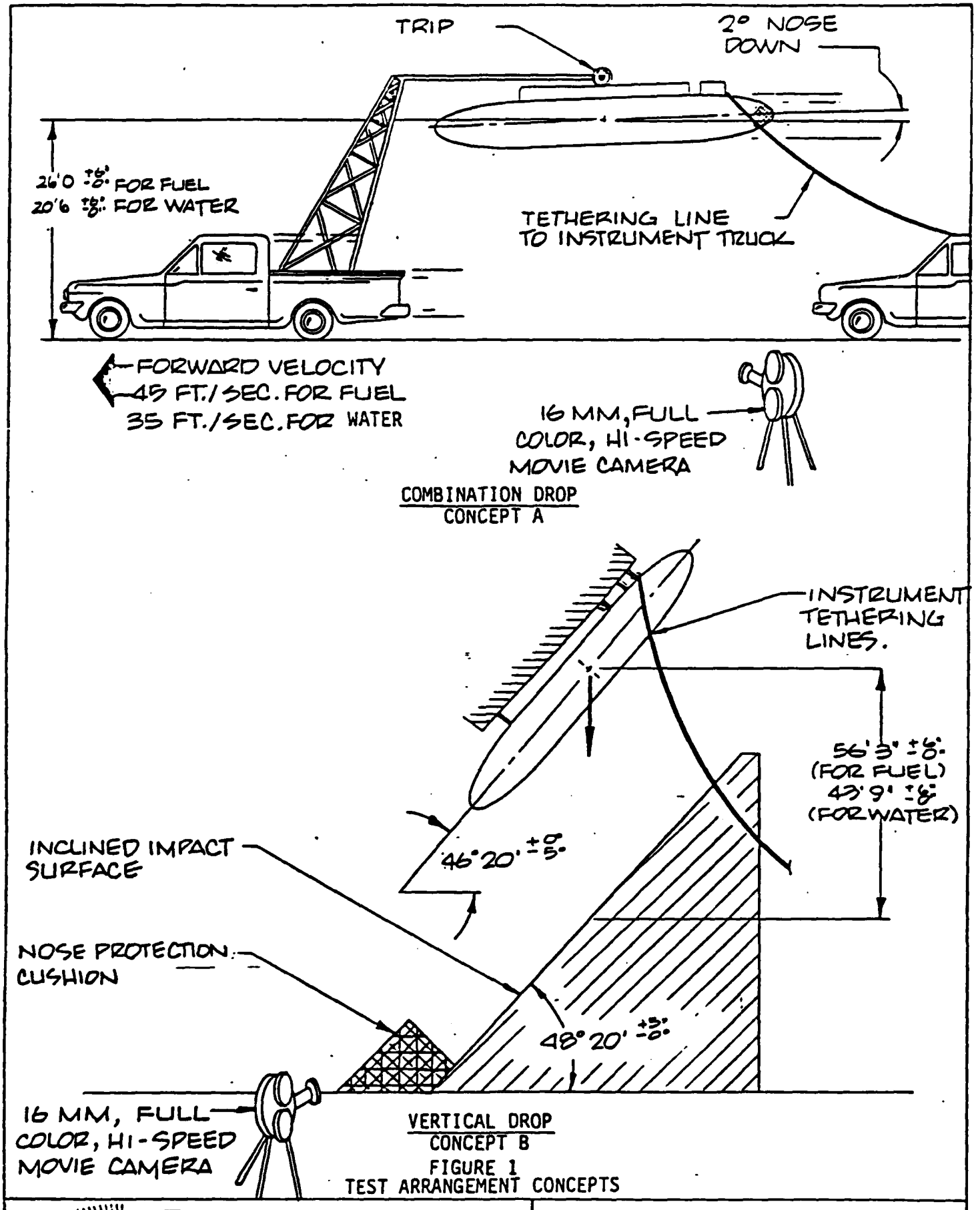
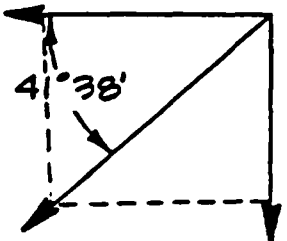


FIGURE 1
TEST ARRANGEMENT CONCEPTS

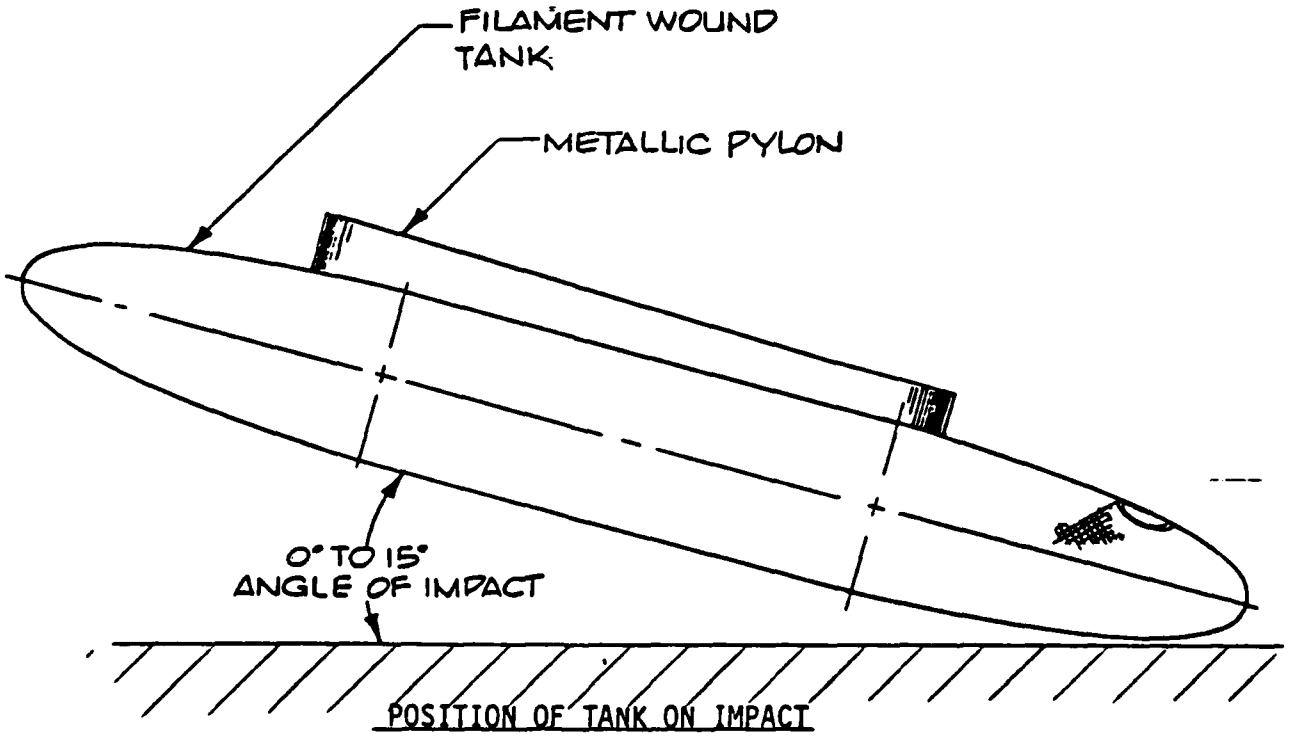
Forward tank velocity component with fuel 45 ± 2 feet per second. Equivalent forward tank velocity component with water 39.6 ± 2 feet per second



Vertical tank velocity component with fuel 40 ± 2 feet per second. Equivalent vertical tank velocity component with water 35.3 ± 2 feet per second.

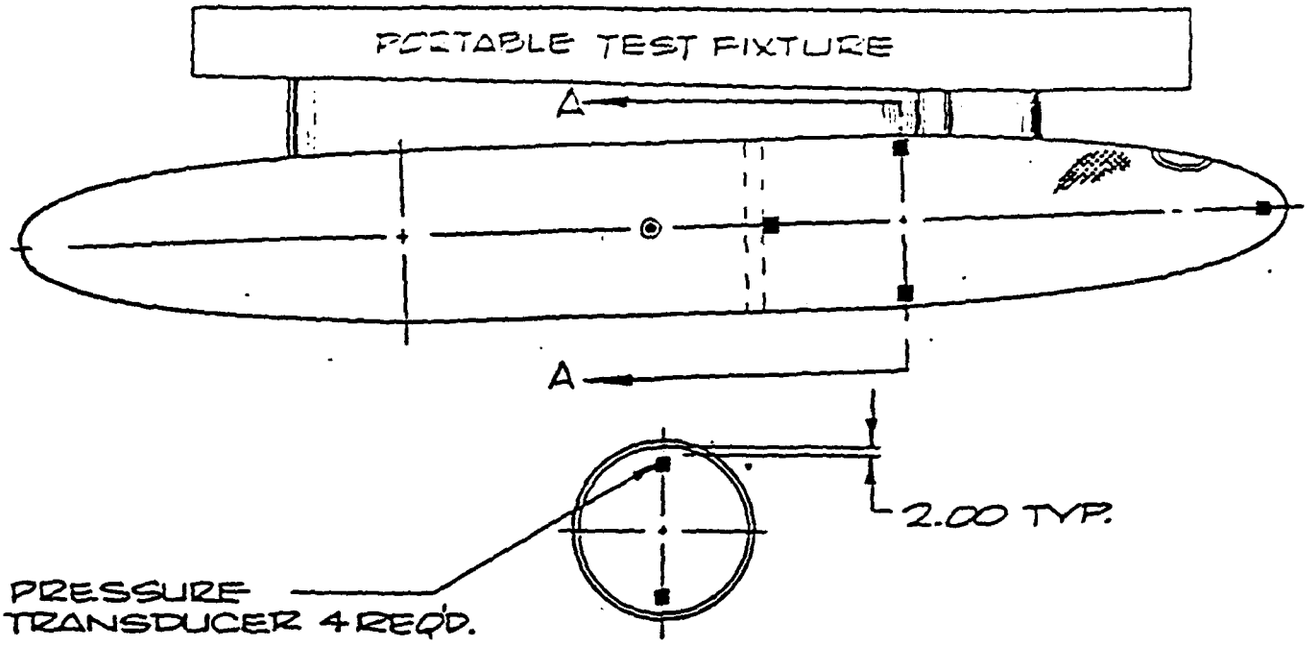
Resultant tank velocity component with fuel 60.2 ± 2 feet per second. Equivalent resultant tank velocity component with water 53.1 ± 2 feet per second.

VECTOR DIAGRAM OF
TANK IMPACT VELOCITY



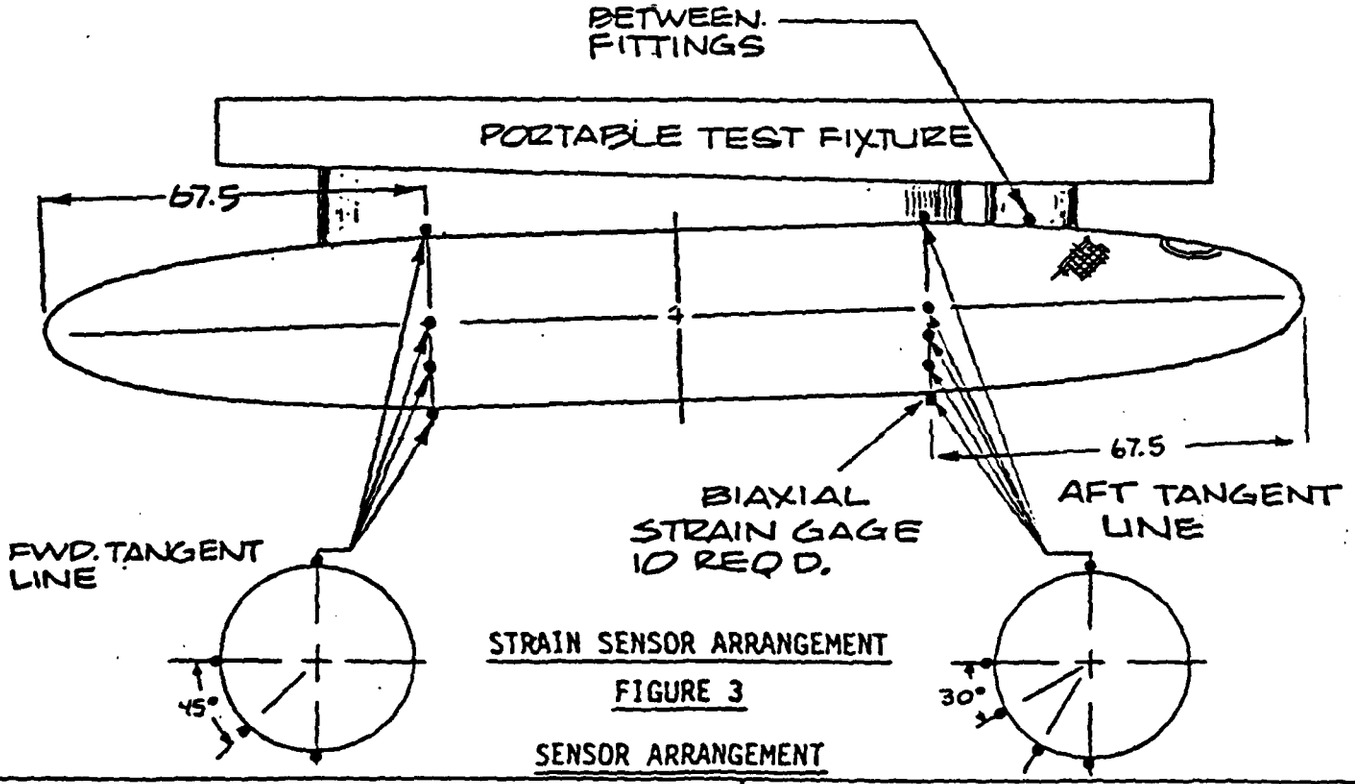
POSITION OF TANK ON IMPACT

FIGURE 2
CRASH IMPACT CONDITIONS



SECTION A-A

PRESSURE SENSOR ARRANGEMENT



STRAIN SENSOR ARRANGEMENT

FIGURE 3

SENSOR ARRANGEMENT

4.0 QUALIFICATION TEST PROVISIONS

4.1 EXAMINATION OF PRODUCT

The tank and pylon shall be fully examined prior to mounting to the portable test rig for shipping damage to the test site. This examination shall include a visual inspection and a tap test for delaminations. The results of this inspection shall be recorded by the testing activity in the presence of an authorized Fiber Science Test Engineer.

4.2 MOUNTING

The tank shall then be mounted to the portable test fixture and examined for proper attachment and assimilation to the actual aircraft installation. Any significant variations or deviations shall be recorded.

4.3 ARRANGEMENT

The test arrangement shall be examined for compliance with Figure I of this procedure or shall be deemed to be in compliance with the applicable paragraphs of ASD/ENFEA-78 Technical Exhibit and approved by an F.S.I. authorized test engineer and an authorized Government representative.

4.4 INSTRUMENTATION AND TEST EQUIPMENT

4.4.1 INSTRUMENTATION CALIBRATION

All instrumentation shall be inspected to verify that each instrumentation has had a calibration check within the last calibration period.

4.4.2 INSTALLATION

All instruments and test equipment: velocity meters, cameras, pressure transducers, strain gauges and recorders shall be installed and leads properly tethered so as to have little or no affect on the test. Pressure and strain readings shall be taken at locations indicated in Figure 3 of this procedure.

4.4.3 OPERATION

All instrumentation and test equipment shall be checked for proper operation. Any defects in instrumentation shall be recorded and the test shall not proceed until the defect is removed or deemed not critical for the test required by the testing activity and approved by an authorized Fiber Science Test Engineer.

4.5 FUELING

The tank shall be filled with 450 to 457 gallons of water through the filler cap opening. The tank properly mounted (2° nose down) during filling will contain the proper amount when the water begins to overflow out the filler cap opening.

4.6 CRASH IMPACT

With all instrumentation synchronized and ready for operation, the tank shall be dropped at the proper speed and angle.

4.7 POST CRASH IMPACT EXAMINATION

4.7.1 LEAKAGE

All leakage from the tank shall be measured where practical. The combined leakage from all ruptures shall not exceed .25 gallons per minute maximum.

4.7.2 RUPTURES

All tank ruptures shall be properly described and accurately located on the tank surface. The exact size of the rupture (width, length and depth where applicable) shall be noted.

4.7.3 NON-RUPTURE DAMAGE

All other damage to the tank surface or fittings shall be recorded including exact location and size.

4.7.4 DELAMINATIONS

The entire tank surface shall receive a tap test to determine if any delaminations occurred outside the impact area. A sketch shall be made showing approximate size and shape.

4.7.5 CRASH IMPACT IMPRINT

The tank impact surface imprint configuration shall be graphically sketched and dimensioned.

4.7.6 PHOTOGRAPHS

At least twelve (12) color photographs of the damaged areas at locations determined by the testing activity and the Fiber Science Test Engineer shall be taken.

4.7.7 DISSECTION

At the discretion of the authorized Fiber Science Test Engineer, the tank may be cross sectioned to determine the internal extent of the crash impact damage.

5.0 QUALIFICATION TEST REPORT

A formal qualification test report shall be submitted per MIL-STD-831 within 30 days after the testing is complete. This report is to include all recorded pressure and strain data sheets, high speed film, photographs and expended tanks. Expended tanks shall be returned to Fiber Science for post evaluation in the same shipping containers they were received in.

APPENDIX "A"

TEST DATA SHEETS

TEST DATA SHEET

QTR-2191 SECTION "S"

Testing Activity_____ Activity Test Engr._____

Tank Serial No. _____ F.S.I. Test Engr. _____

Test Date _____ Government Rep. _____

EXAMINATION OF PRODUCT

Ref. Para. 4.1: Visual Inspection _____

_____

_____

_____

_____

Delaminations (Tap Test)_____

_____

_____

_____

_____

MOUNTING

Ref. Para. 4.2: Aircraft Simulated Attachment

Deviations If Any_____

_____

_____

_____

_____

ARRANGEMENT

Ref. Para. 4.3: Approved Test Arrangement (Ref. Figure 1 & ASD/ENFEA-78 Technical Exhibit.)

Testing Activity Approval

Approved By_____ Date_____

F.S.I. Test Engineer Approval

Approved By_____ Date_____

Government Approval

Approved By_____ Date_____

Minimum of two signatures required.

INSTRUMENTATION

Ref. Para. 4.4.1: CHECK INSTRUMENTATION CALIBRATION

ITEM	CALIBRATION DATE
Speedometer (If applicable)	_____
Cameras (If applicable)	_____
Pressure Transducer Recorder	_____
Strain Gauge Recorder	_____
Other Instruments	_____
1._____	_____
2._____	_____
3._____	_____
4._____	_____

Ref. Para. 4.4.2: CHECK PROPER INSTALLATION

ITEM	REMARKS
Tank	
Speedometers	
Cameras	
Pressure Transducers	
Strain Gauges	
Recorders	
Other Instruments	
1. _____	
2. _____	
3. _____	
4. _____	

Ref. Para 4.4.3: CHECK PROPER OPERATION

ITEM	REMARKS
Speedometers	
Trip Mechanism	
Cameras	
Pressure Transducers	
Recorders	
Other Instruments	
1. _____	
2. _____	
3. _____	
4. _____	

FUELING

Ref. Para 4.5: FUEL TANK AT PROPER ATTITUDE

ITEM	REMARKS
Attitude (2^{0} Nose Down)	
Fill with 450 Gal. Water	
Secure Filler Cap	

CRASH IMPACT TEST

Ref. Para. 4.6: DROP TANK WITH ALL INSTRUMENTATION SYNCHRONIZED

ITEM	OPERATION REMARKS
Speedometers	
Trip Mechanism	
Cameras	
Pressure Transducers	
Strain Gauges	
Recorders	
Other Instruments	
1.	
2.	
3.	
4.	

POST CRASH IMPACT EXAMINATION

Ref. Para. 4.7: General Appearance

_____

_____

_____

_____

Ref. Para. 4.7.1: LEAKAGE

Amount At Each Location

1. _____
2. _____
3. _____
4. _____

Ref. Para. 4.7.2: RUPTURES

Locations

1. _____
2. _____
3. _____
4. _____

Extent of Damage

1. _____
2. _____
3. _____
4. _____

Ref. Para. 4.7.3 NON-RUPTURE DAMAGE

Final Distortion of Cross Sectional Shape

END CLOSURES

Nose Cap

Tail Cap

PYLON CONDITION

FUEL & AIR FITTING CONDITION

Ref. Para. 4.7.4: DELAMINATIONS

Results of Tap Test for Delaminations

(Supply scaled sketch of size, location and approximate shape).

Ref. Para. 4.7.5: CRASH IMPACT IMPRINT

Describe Damaged Condition of Impacted Area of the Tank

_____

_____

_____

(Supply a scaled sketch of the size and approximate shape of impact area.)

Ref. Para 4.7.6: PHOTOGRAPHS

Number Photographs and Identify Locations

PHOTO	LOCATION	PHOTO	LOCATION
1.	_____	7.	_____
2.	_____	8.	_____
3.	_____	9.	_____
4.	_____	10.	_____
5.	_____	11.	_____
6.	_____	12.	_____

Ref. Para. 4.7.7 DISSECTION OF THE TANK

Approved By_____ Date_____

Condition of Frames

_____

_____

Condition of Probe

_____

_____

Condition of Float Switches

Condition of Fuel Line

APPENDIX F

Complete Listing of
35 mm Test Photographs

TEST T3-2, SN0004

B1-1: Pre-Test Right Side View of Tank on Crane

B1-2: Pre-Test View of Aft Pylon Mount Interface

B1-3: Pre-Test View of Fore Pylon Mount Interface

B1-4: Pre-Test View of Tank Angle Setting

B1-5: Pre-Test Left Front View of Crane and Tank

B1-6: Pre-Test Left Front Underside View of Tank on Crane

B1-7: Pre-Test Rear Underside View of Tank on Crane

B1-8: Pre-Test Left Side View of Tank on Crane

B1-9: Pre-Test Left Side View of Mounting Fixture

B1-10: Post-Test Left Rear View of Tank at Impact Site

B1-11: Post-Test Left Side Close-Up Ground Level View of Major Aft Rupture

B1-12: Post-Test Left Side Ground Level View of Tank Rear

B1-13: Post-Test Right Side Close-Up of Tank Tail

B1-14: Post-Test Left Side Close-Up of Center Section of Tank

B1-15: Post-Test Close-Up Top View of Tank Nose

B1-16: Post-Test Close-Up Top View of Tank Tail Section

B1-17: Post-Test Close-Up Left Side View of Tank Aft Section

B1-18: Post-Test Overall Right Rear View of Tank

B1-19: Post-Test Overall Left Rear View of Tank

B1-20: Post-Test Left Front View of Tank

B1-21: Post-Test Close-Up Left Side View of Major Forward Rupture

B1-22: Post-Test Close-Up Left Side View of Major Forward Rupture

B1-23: Post-Test Rear View of Impact Site

B1-24: Post-Test Rear View of Impact Site

B1-25: Post-Test Overall Left Side View of Tank

B1-26: Post-Test Close-Up Top View of Fuel and Air Fittings

B1-27: Post-Test Right Side View of Front of Pylon

B1-28: Post-Test Right Side View of Aft Section of Tank

B1-29: Post-Test Top View of Aft Section of Tank

B1-30: Post-Test Close-Up Left Rear View of Tank

B1-31: Post-Test Close-Up Left Side View of Tank Nose

B1-32: Post-Test Close-Up Right Side View of Major Aft Rupture

B1-33: Post-Test Close-Up Right Side View of Major Forward Rupture

B1-34: Post-Test Overall Right Side View of Tank

B1-35: Post-Test Right Side View of Forward Section of Tank

B1-36: Post-Test Overall Right Front View of Tank

B1-37: Post-Test Overall Bottom View of Tank

B1-38: Post-Test Close-Up Bottom View of Tank Nose

B1-39: Post-Test Close-Up Bottom View of Tank Tail

B1-40: Post-Test Close-Up Bottom View of Major Forward Rupture

B1-41: Post-Test Close-Up Bottom View of Major Aft Rupture

B1-42: Post-Test Bottom View of Forward 3/4-Section of Tank

B1-43: Post-Test Bottom View of Forward Section of Tank

B1-44: Post-Test Bottom View of Aft Section of Tank

TR-04-01: Left Side Overall View of Crane and Tank Just Prior to Test Run

TR-04-02: Test Run View of Crane Boom and Tank on Approach

TR-04-03: Test Run View of Tank in Free-Fall

TR-04-04: Test Run View of Tank Shortly After Impact

TEST T4-1, SN0002

B1-45: Pre-Test View of Rear Half of Tank on Crane

B1-46: Pre-Test View of Front Half of Tank on Crane

B1-47: Pre-Test Left Rear View of Tank on Crane

B1-48: Pre-Test Rear Underside View of Tank on Crane

B1-49: Pre-Test Right Side Overall View of Tank on Crane

B1-50: Pre-Test Right Side View of Tank/Ground Relationship

B1-51: Pre-Test Right Rear View of Tank on Crane

B1-52: Pre-Test Right Front View of Crane and Tank

B1-53: Pre-Test Left Front View of Crane and Tank

B1-54: Post-Test Rear View of Tank

B1-55: Post-Test Front View of Tank

B1-56: Post-Test Overall Top View of Tank

B1-57: Post-Test Close-Up Top View of Tank Tail and Filler Access

B1-58: Post-Test Close-Up View of Fuel and Air Fittings
B1-59: Post-Test Overall Left Front View of Tank
B1-60: Post-Test Close-Up Bottom View of Front Rupture
B1-61: Post-Test View of Impact Site
B1-62: Post-Test Close-Up Left Front View of Front Rupture
B1-63: Post-Test Overall Bottom View of Tank
B1-64: Post-Test Rear Underside View of Tank
B1-65: Post-Test Close-Up Rear Underside View of Tank
B1-66: Post-Test Top Left View of Pylon
B1-67: Post-Test Close-Up View of Pylon/Tank Contact Area
B1-68: Post-Test Close-Up Bottom View of Rear Rupture
B1-69: Post-Test Overall Left Rear View of Tank
B1-70: Post-Test Overall View of Tank at Impact Site
B1-71: Post-Test Overall View of Tank at Impact Site
B1-72: Post-Test Left/Bottom View of Tank Front Section
B1-73: Post-Test Extra Close-Up Bottom View of Front Rupture
B1-74: Post-Test Extra Close-Up Right Side View of Front Rupture
B1-75: Post-Test Right Side View of Tank Front Section
B1-76: Post-Test Right Side View of Tank
B1-77: Post-Test Right Side View of Tank Aft Section
B1-78: Post-Test Overall Right Side View of Tank
B1-79: Post-Test Bottom View of Aft Section of Tank
B1-80: Post-Test Extra Close-Up Right Side View of Aft Rupture
B1-81: Post-Test Bottom View of Tank Center Section
TR-02-01: Test Run View of Crane and Tank on Approach
TR-02-02: Test Run View of Crane and Tank on Approach
TR-02-03: Test Run View of Tank on Crane on Approach
TR-02-04: Test Run View of Tank on Crane Prior to Release
TR-02-05: Test Run View of Tank in Free-Fall
TR-02-06: Test Run View of Tank Shortly After Impact
TR-02-07: Post-Test View of Tank at Impact Site
TR-02-08: Post-Test View of Tank at Impact Site
TR-02-09: Post-Test View of Tank at Impact Site
TR-02-10: Post-Test Bottom View of Tank Aft Section